

AN ILLUMINATING INTRODUCTION TO ANTENNAS.

A Series of Demonstrations By Dale P. Clement, AF1T
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BASIC ANTENNAS – AN ILLUMINATING INTRODUCTION.

This was originally an attempt to visually convey the concepts encountered in studying for the entry-level Technician Class Amateur Radio License. The program can be broadened or tailored for the benefit of various groups, such as Physics or Electronics classes, Science and Technology (STEM) classes, Boy Scout Radio Merit Badge students, Science Museums, and Engineering Conferences.

Various properties of Radio Frequency (RF) energy and communications are demonstrated, with working antenna models set up to transmit and receive 432 MHz radio energy across a room, and detected by small light bulbs. Use of light bulbs instead of meters is more dramatic and less mathematical, an important consideration for newcomers. 432 MHz (UHF) was chosen because of available equipment, and because practical antennas are small enough to easily transport, and yet not too critical to build at home. Many antenna types have been constructed from ordinary No.10 or No. 12 house-wire and simple wooden supports.

Several parts of the Demonstration lend themselves to audience participation. Many topics may be covered, or just a few if time is limited. Initial success has led to expanded programs which cover more advanced topics, such as those encountered in the General Class and Extra Class Amateur Radio exams.

Here is a List of some Demonstration Topics:

- Comparison of Sound, Light and Radio Waves.
- Wave Length and Frequency.
- Electromagnetic Waves.
- Electric and Magnetic Fields.
- Velocity and the Speed of Light.
- Modes of Propagation.
- The Inverse-Square Law.
- Polarization – Horizontal and Vertical.
- Cross-Polarization
- “Spin-Fading” and Circular Polarization.
- The Isotropic Radiator.
- The Half-Wave Dipole.
- Shortened and Bent Dipoles.
- Inductively-Loaded and End-Loaded Dipoles.
- The Quarter-Wave Vertical Monopole.
- The Ground-Plane Antenna.
- Gain and Directivity.
- Beamwidth.
- Front-to-Back Ratio.

Bandwidth

Directional or “Beam” Antennas -

Yagi Reflectors and Directors.

The Moxon Rectangle.

Quad Loops and Cubical Quads.

Delta Loops and Circular Loops.

Environment and Reflections.

“Picket-Fencing”.

Detuning of Elements.

Effects of Mast-Mounting.

Near-Vertical Incidence Skywave (NVIS) Antennas.

Multiband Antennas and Traps.

Small Loops and Halos.

“Edible” Antennas.

Modulation – CW, AM, and DSB.

A Simple Crystal Radio for 432 MHz.

Safety.

Decibel Discussion (Handout).

AN ILLUMINATING INTRODUCTION TO ANTENNA STACKING AND PHASING.

This continues the series of demonstrations to show the effects of lengthening dipole elements, as well as combining multiple antennas, on gain and directivity. There is an overlap of topics, which may be presented in conjunction with the previous Basic Introduction.

Here is a list of some Demonstration Topics:

The End-Fed Dipole (Zepp or J-Pole).

The Full-Wave Doublet (Double-Zepp).

The Extended Double-Zepp (EDZ).

Long Wires/Harmonic Operation.

Phasing and Matching Stubs.

Stacked Dipoles -

Broad-side Stacking.

End-Fire Stacking.

Co-linear Stacking.

Stacked Yagis.

Phasing Cables and Delay-Lines.

Power Dividers and Power Combiners

Driven-Element Matching Methods -

The Gamma Match.

The Beta Match.

The T-Match.

The Hair-Pin Match

Goals of Stacking – HF vs. VHF Operation.

AN ILLUMINATING INTRODUCTION TO CLASSIC ANTENNAS.

The Demonstration of Stacking and Phasing leads to some clever configurations and wire arrays of historic significance, some of which were developed during the 1920's and 1930's. Most of these antennas are more commonly associated with HF than with UHF (432 MHz). Some, such as the Rhombic, are so large for HF that most Amateurs only dream about them; UHF versions can fit in a room. This incomplete listing does not include all the ingenious ideas that have been tried over the years. If you have a favorite that has been omitted, please let me know; it might be interesting to fabricate and test a 432 MHz model. An understanding of basic Stacking and Phasing concepts is important here, so this Presentation may overlap the previous one.

Here is a list of demonstration topics:

- Current-Fed and Voltage-Fed Wires.
- The Co-linear or Franklin Array.
- The Broad-side Dipole Array.
- The "Lazy H" Array.
- The Half-Square Array (Bidirectional).
- The Half-Square with Reflector (Unidirectional).
- The Bob-Tail Curtain Array.
- The Bruce Array.
- The Sterba Curtain Array
- The V-Beam
- The Unterminated Rhombic (Bidirectional).
- The Terminated Rhombic (Unidirectional).
- Corner Reflectors.
- Parabolic Reflectors (Discussion).
- Driven vs. Parasitic Arrays.
- The "ZL-Special" Array.
- The Log-Periodic Beam.

TECHNICAL DISCUSSION OF ANTENNA DEMONSTRATIONS.

Various Properties of Radio Frequency (RF) energy and Antennas are shown visibly by using small lamps as detectors, in a somewhat darkened room. These lamps must respond to 432 MHz. I chose this frequency because an entire arsenal of UHF antennas will fit into a suitcase or on a table top; a half-wave dipole is only about 13 inches (33 cm) long. Besides, I have the equipment – an old Microwave Modules MMT-432/28 Transverter generates several watts at 432 MHz when driven by a few milliwatts at 28 MHz from a home-built exciter. This small unit (3 in x 5 in x 2 in) has variable carrier and audio levels to permit transmission of CW (Morse Code), AM (Amplitude Modulation), and DSB (Double Side-Band Suppressed-Carrier). It contains a 28.32 MHz crystal oscillator, doubly-balanced mixer, and MMIC amplifier. The 432 MHz energy is fed to a small directional antenna, which is aimed away from the audience (heed the RF safety rules!). A simple easy-to-make candidate is the WA5VJB " Cheap Yagi", with 1/8 in. diameter aluminum-wire elements on a wooden boom. Mine is a two piece eight-element version (airline transportable), which may be rotated for horizontal or vertical polarization. Remember to identify your call-sign every ten minutes when transmitting in the Amateur

band – the signal is traveling well beyond the room!

432 MHz models of many antenna types can be readily constructed from No. 10 or No. 12 house-wire and wooden support structures. No fancy hardware is needed. Construction for frequencies much higher than 432 MHz would be complicated by critical lead-lengths and tight tolerances. Some of my antennas have BNC jacks and are optimized for 50 ohm loads. Others have no connectors and are adjusted for maximum brilliance in soldered-on wire-lead lamps. Building these has proven to be a highly enjoyable and educational experience. I have gained an empirical feel for numerous designs that goes beyond reading about them. To anyone wishing to teach this subject, I highly recommend that you study the ARRL Antenna Book, and concoct/construct your own working antennas. You will be rewarded, and become a better teacher. Of course, commercially available antennas may be compared to your home-built ones, and you may be gratified when yours perform as well or better! Investigating various antenna ideas by fabricating models for HF (below 30 MHz) rather than for UHF (432 MHz) would require lots of time, money, and real-estate.

Using small incandescent lamps as detectors can dramatically reveal the presence and properties of radio energy to newcomers and old-timers alike. Field-strength meters may be more sensitive and accurate, but they are just not as exciting! I try to keep far enough away from the source antenna to prevent a lamp from getting too bright and burning out. Good lamp types include No. 49 ([2.0 V @ 60 mA](#)), and so-called “grain-of-wheat” bulbs with wire-leads (such as the Radio Shack No. 272-1139, [1.5 V@25 mA](#)). More powerful types such as the No. 47 ([6.3 V@150 mA](#)) are not sensitive enough over great distances, without increasing the source power to an unsafe level. The smaller lamps are practical in a 10 ft. to 30 ft. space, with only a few watts from the source transmitter.

One problem with incandescent lamps is their non-constant impedance with changes in temperature. For example, a No. 49 lamp measured 5.1 ohms when cold (4.6 ohms for a Chinese version), and is calculated to have 33 ohms with 2 V applied. This will of course differ at 432 MHz, due to lead inductance and distributed capacitance. I solder my No. 49 lamps to short RG-58/U cables attached to BNC connectors. Some of my antennas have built-in directly-soldered “grain-of-wheat” lamps with shortened leads.

I have also experimented with bright Light-Emitting Diodes (LED's). They are indeed more sensitive and require less energy to operate than incandescent lamps do, but need a DC power supply, since 432 MHz is too high a frequency. My typical LED detector is mounted on a small (5/8 in. square) circuit-board containing a hot-carrier diode (HP-2800), small bypass-capacitor (100 pF), and current-limiting resistor (20 to 50 ohms). My most sensitive detector lights over 100 ft. from the source, and uses a voltage-doubler (two diodes plus two capacitors) to deliver the necessary drive.

LED's also vary their impedance with changes in brightness, but in the opposite direction from incandescent lamps. A red LED requires approximately 2 V just to turn it on. At low current levels (less than 100 microamps) it may exhibit thousands of ohms, whereas at full brilliance (20 or 30 mA, at somewhat over 2 V), this will drop to under 100 ohms. A result is that the CHANGE in brightness will be less pronounced for an LED than for an incandescent detector, when moving an antenna. Green, blue, or white LED's need an even higher turn-on voltage than red ones, typically 3 or 4 V.

Many LED's emit a light beam that is too directional for audience viewing. Some of the 4-pin square units are very bright over a wide viewing-angle. A good candidate is the Radio Shack 276-0020 Red LED, with a viewing-angle of 140 degrees, and 70 mA current rating. The Radio Shack 276-0027

Green LED and the 276-0024 White LED have viewing-angles of 130 degrees, and draw 20 mA at 3.5 V, but will not be as bright. As with building antennas, these visual detectors are interesting and educational to experiment with. Perhaps you can make some improvements. Please let me know.

Should you re-create a demonstration similar to mine, be sure to gauge your audience. The topic possibilities are extensive, but for many people, a few simple activities such as rotating an antenna to show polarization, or holding up a dipole and reflector/director on wooden sticks (with audience participation!) to make a simple Yagi, will suffice. If you have an engineering background, keeping this simple may be difficult. Avoid overwhelming your audience with long-winded technical or mathematical dissertations about complex-impedances, mutual-coupling, or grating-lobes. Always remember that some of the best learning is visual and hands-on. Share your enthusiasm without scaring them away!

A TRANSMISSION-LINE TUTORIAL.

This “show-and-tell” Presentation is related to the Illuminating Introduction to Antennas series, but may be given independently. The original intent was to explain the topics encountered in all the Amateur Radio License exams, but this has been broadened to demonstrate related aspects of conveying radio energy that are not covered by the antenna series.

Here is a List of some Topics:

Decibel Discussion (handout).

Common Transmission-Line Types -

Balanced-Conductor Lines:

Open-Wire, Window, Twin-Lead, Twisted-Pair.

Advantages and Disadvantages.

Coaxial Cables:

Air-Dielectric, Solid-Dielectric, Foam-Dielectric, Semi-Rigid, “Hard-Line”.

Advantages and Disadvantages.

Velocity Factor.

Characteristic Impedance.

Strip-Line.

Microstrip-Line.

Wave-Guides.

Transmission-Line Losses -

Ohmic (Conductor) Loss.

Dielectric Loss.

Radiation Loss.

Mismatch Loss.

Connector Losses.

Estimating Line Loss.

Common Coaxial Connectors -

Types UHF, N, BNC, SMA.

Advantages and Disadvantages.

Weather-Proofing Connectors.

Transmission-Lines as Circuit Components -

Tuned (Resonant) Stubs.

Capacitors and Inductors.

The $1/4$ -Wave Length "Impedance Inverter".

The $1/2$ -Wave Length "Impedance Repeater".

The Non-Synchronous Transformer.

Transmission-Line Measurements -

Standing-Wave Ratio (SWR).

Return-Loss.

Antenna Analyzers.

Directional Watt-Meters.

Noise-Bridges.

A Return-Loss Bridge and Detector.

Dip-Meters.

Dummy Loads.

Attenuators

Circulators and Isolators

Miscellaneous Equipment -

Antenna Tuners.

Field-Strength Meters.

Interference Filters and Ferrite Beads.

Band-Pass and Notch Filters

BALUNs and UNUNs.