ARRAY ANTENNAS

ECE 515E – ANTENNA & RADIO WAVE PROPAGATION

Thursday, 12 October 2023

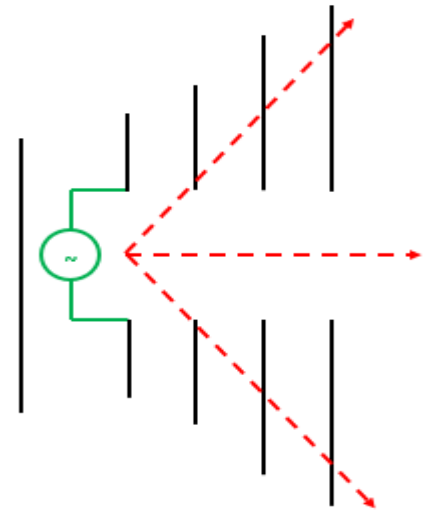
DEFINITION OF ANTENNA ARRAYS

1. An **antenna array** is an antenna that is composed of more than one conductor

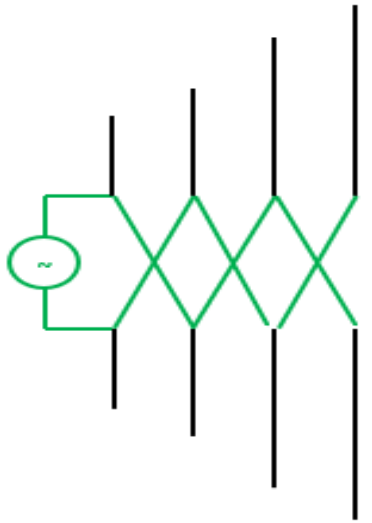
2. There are two types of antenna arrays:

(a) Parasitic arrays – Only one element is connected to the transmitter. The other elements are coupled to the driven element through the electric fields and magnetic fields that exist in the near field region of the driven element

(b)Driven arrays – All elements in the antenna are fed RF from the transmitter



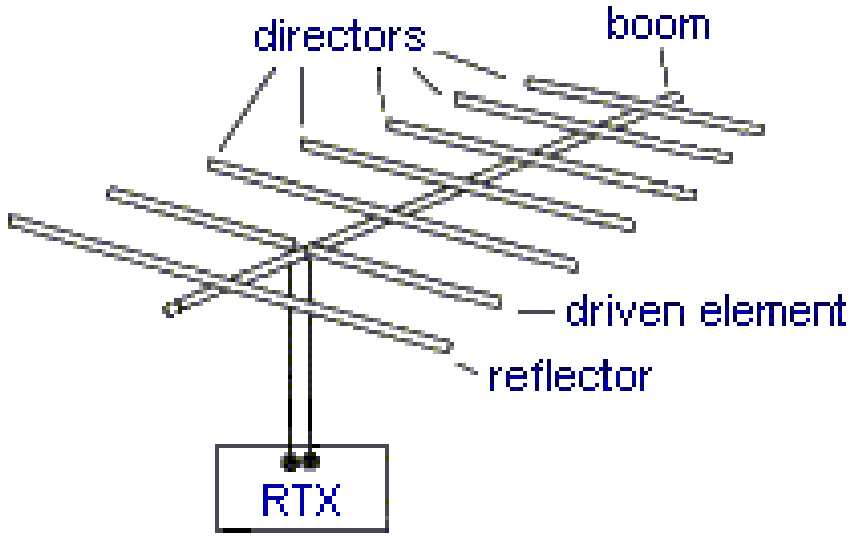
(b) Parasitic array



(a) Driven array

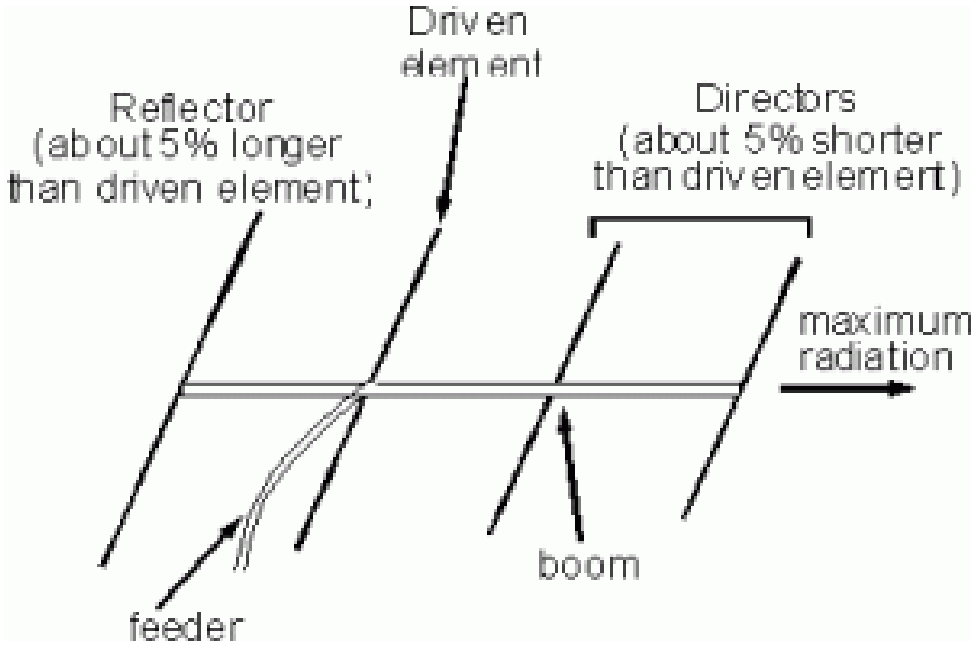
PARASITIC ANTENNA

1. A parasitic array consists of a basic antenna connected to a transmission line plus one or more additional conductors that are not connected to the transmission line.
2. These extra conductors are referred to as parasitic elements.
3. The element connected to the transmitter is referred to as the driven element.

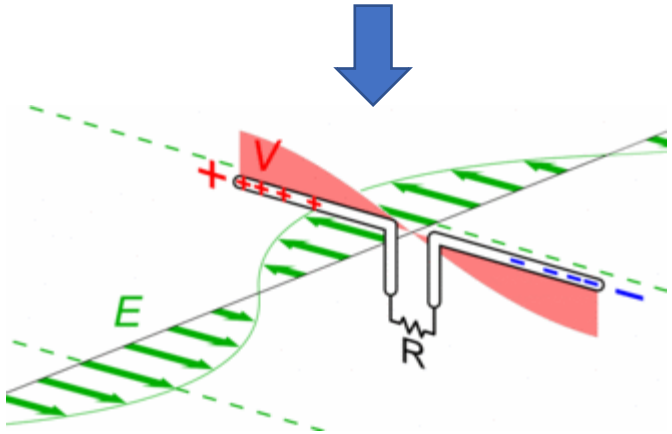


THE DRIVEN ELEMENT

1. The driven element is usually a half-wave dipole or its variation.
2. The parasitic elements are slightly longer than and slightly less than one-half wavelength long.
3. The parasitic elements are placed in parallel with and near the driven elements.
4. The elements of the antenna are all mounted on a common boom.



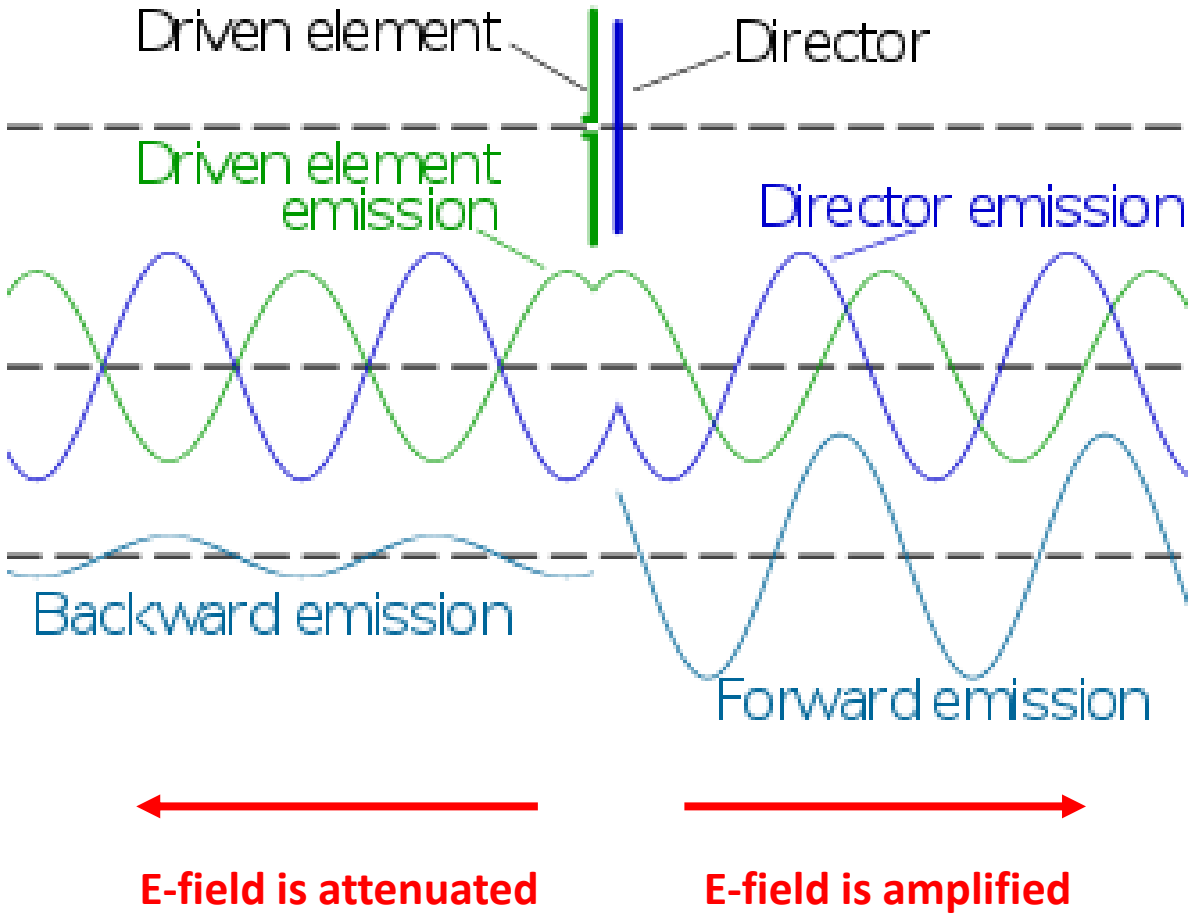
5. The boom does not have to be an insulator since there is a voltage null at the center of a one-half wavelength conductor at the resonant frequency, there is no potential difference between the elements and so they can all be connected to a conducting boom with no undesirable effect.



HOW GAIN IS ACHIEVED WITH THE ADDITION OF A PARASITIC ELEMENT

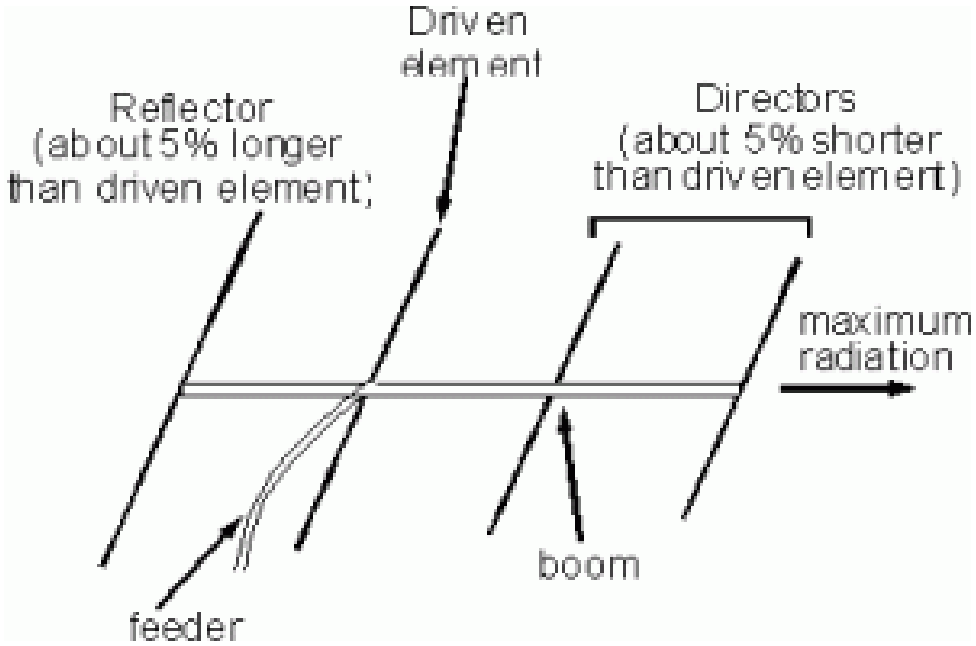
- **Due to the reactance caused by the length difference**, the phase lag of the current in the reflector, added to 180° lag, results in a phase advance, and vice versa for the director.

- As a result, the gain of the array is in the direction towards the director.



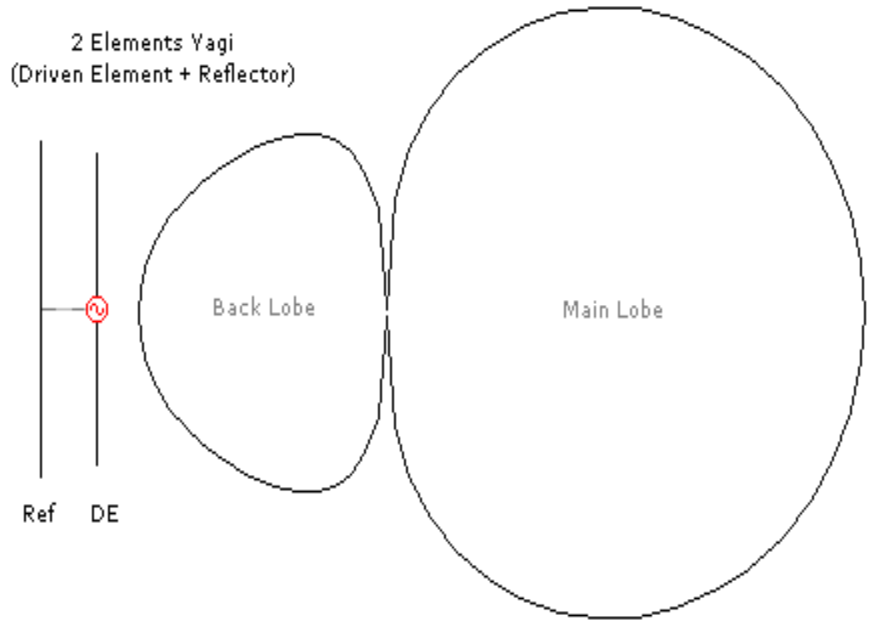
THE REFLECTOR

- **Reflector** is a parasitic element that is typically about 5 percent longer than the half-wave dipole-driven element.
- It is spaced from the driven element by a distance of 0.15 to 0.25λ.



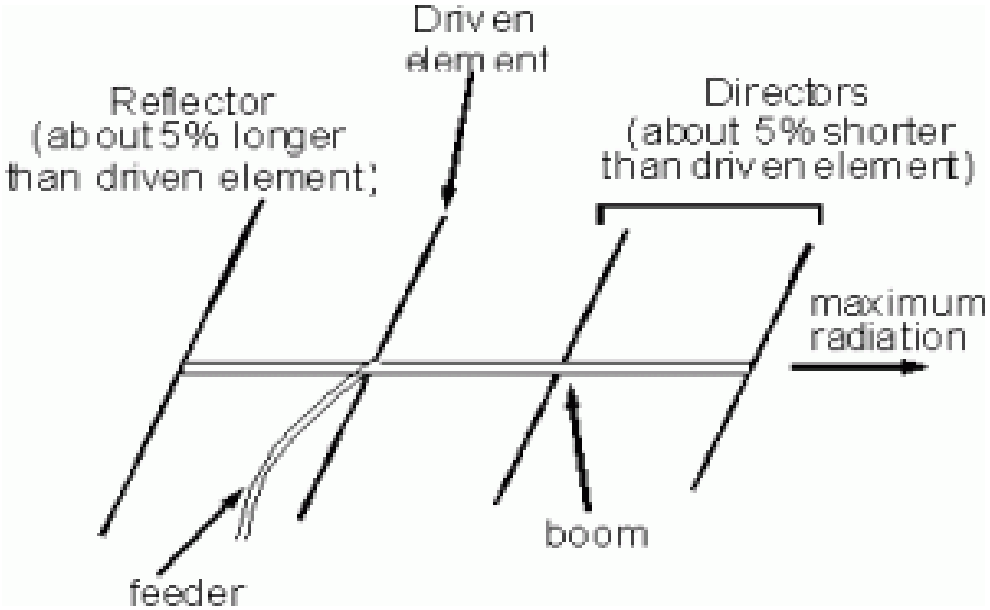
HOW RADIATION IN THE REVERSE DIRECTION IS MINIMIZED BY THE REFLECTOR

1. When the signal radiated from the dipole reaches the reflector, it induces a voltage into the reflector and the reflector produces some radiation of its own. Because of the spacing, the reflector's radiation is mostly in phase with the radiation of the driven element.
2. As a result, the reflected signal is added to the dipole signal, creating a stronger, more highly focused beam in the direction of the driven element.
3. Consequently, the reflector minimizes the radiation to the right of the driven element and reinforces the radiation to the left of the driven element



DIRECTOR

- A director is approximately 5% shorter than the half-wave dipole driven element and is mounted in front of the driven element.
- The directors are placed in front of the driven element and spaced by some distance between approximately 1/10 and 2/10 of a wavelength from the driven element.

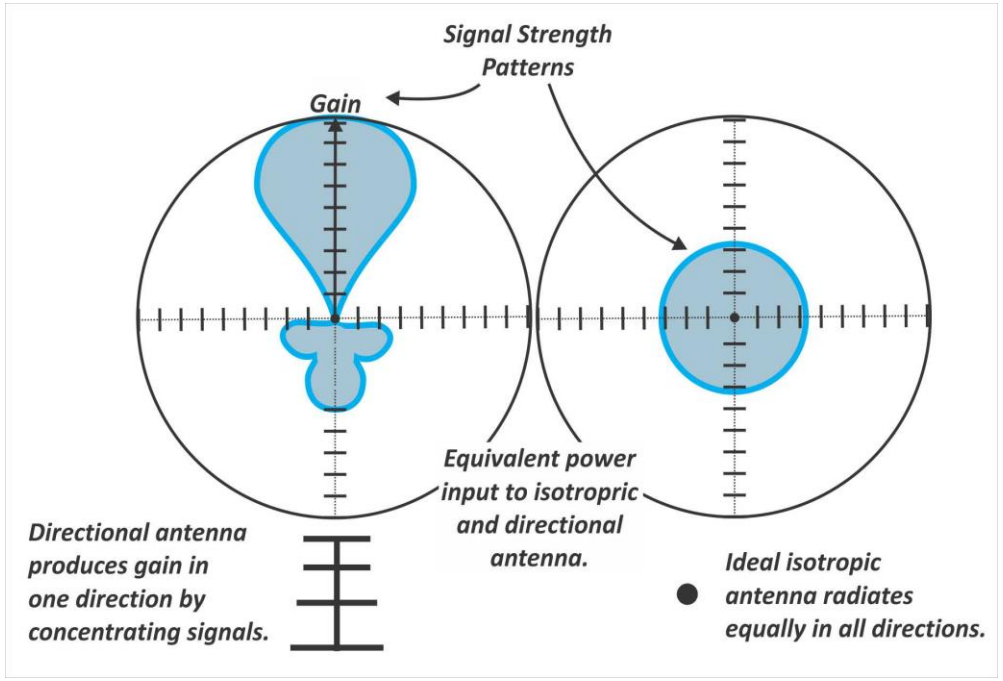


CLASS EXERCISE

1. Examine the two Yagi antennas in the lab.
2. Read the resonant frequency
3. Compute the wavelength at the resonant frequency
4. Measure the distance between the driven element and the first director
5. Measure the distance between the subsequent directors
6. Write the inter-element distances as fractions of the wavelength
7. Discuss the results

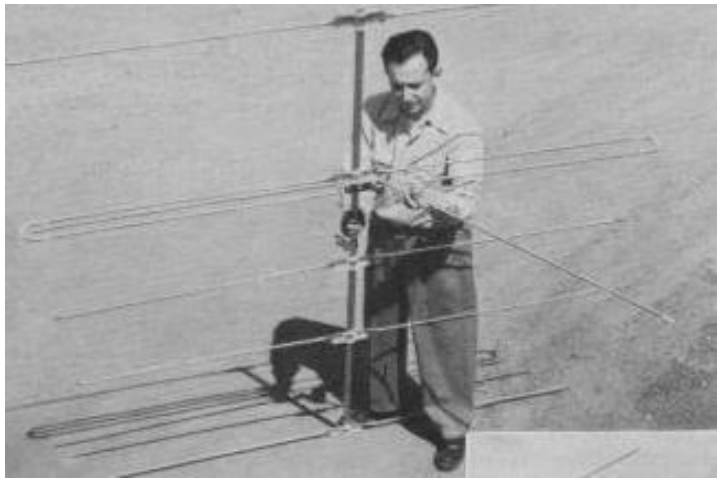
HOW GAIN IS ACHIEVED WITH THE ADDITION OF DIRECTORS

1. The signal from the driven element causes a voltage to be induced into the director.
2. The signal radiated by the director then adds in phase to that from the driven element.
3. The result is increased focusing of the signal, a narrower beam width, and a higher antenna gain in the direction of the director.



YAGI-UDA ANTENNA

1. The most commonly used TV antenna is made up of a driven element and one or more parasitic elements is generally referred to as a **Yagi antenna,** after one of its inventors, Hidetsugu Yagi.

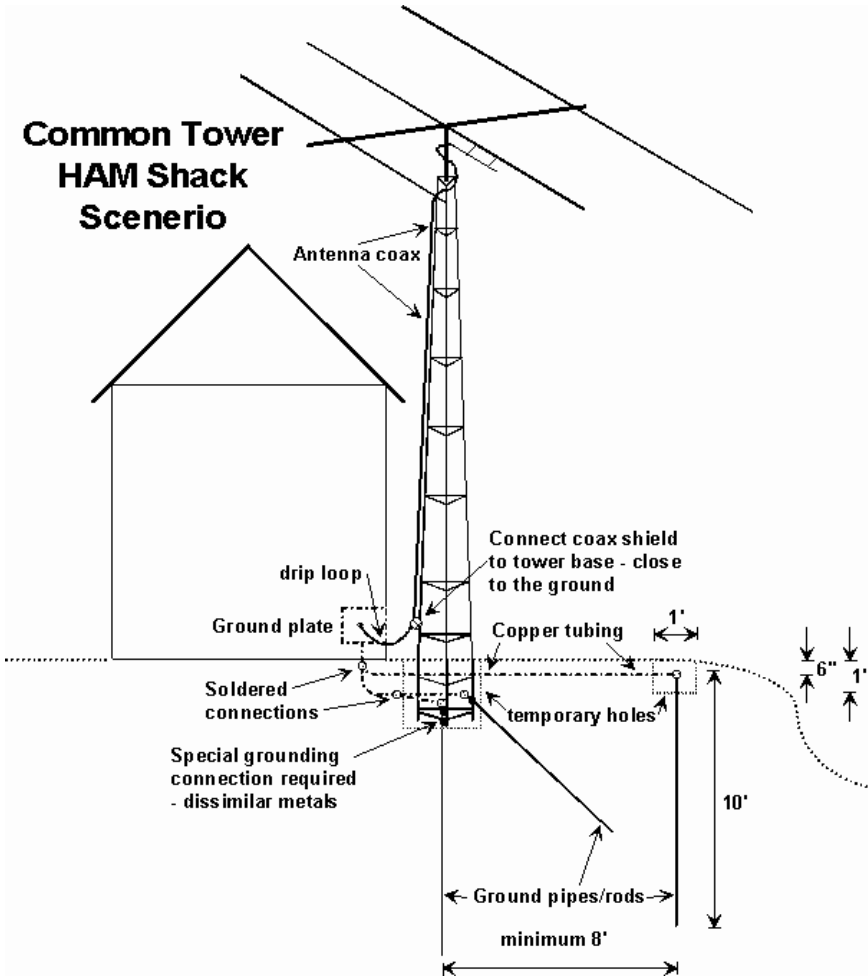


2. The antenna elements are usually made of aluminium tubing and mounted on an aluminium cross member or boom.

INSTALLATION OF YAGI-UDA ANTENNA

- Since the centers of the parasitic elements are neutral electrically, these elements can be connected directly to the boom.

- For the best lightning protection, the boom can then be connected to a metal mast and electrical ground.

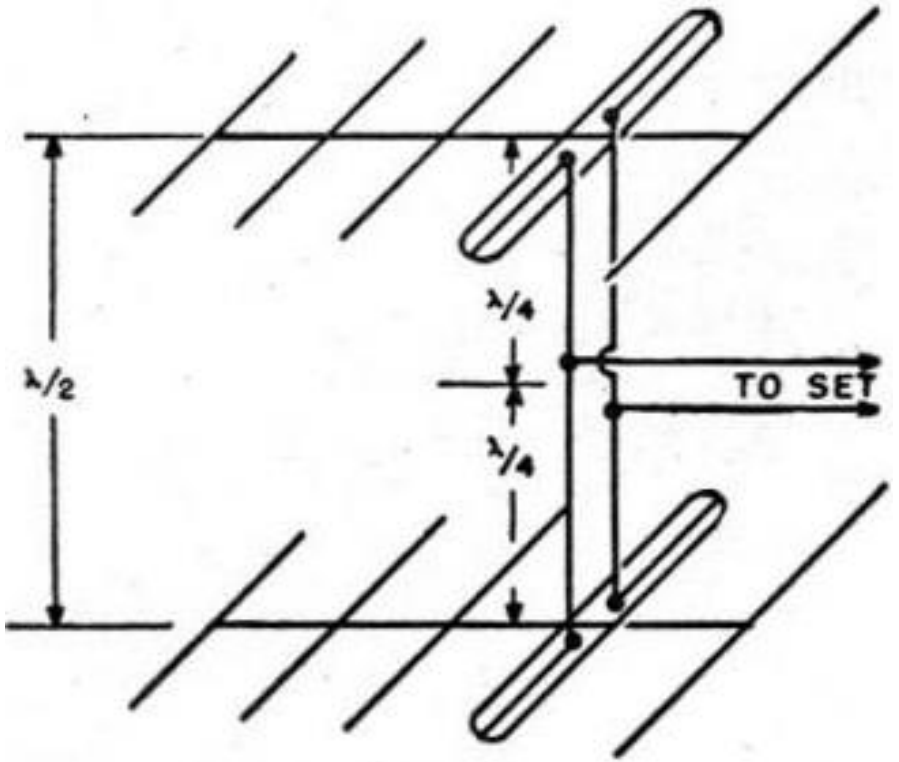


IMPEDANCE OF THE YAGI ANTENNA

- The drive impedance of a Yagi varies widely with the number of elements and the spacing.
- The parasitic elements greatly lower the impedance of the driven element, making it less than 10 Ohms in some arrangements.
- Typically, some kind of impedance-matching circuit or mechanism must be used to attain a reasonable match to 50-Ohm coaxial cable, which is the most commonly used feed line.

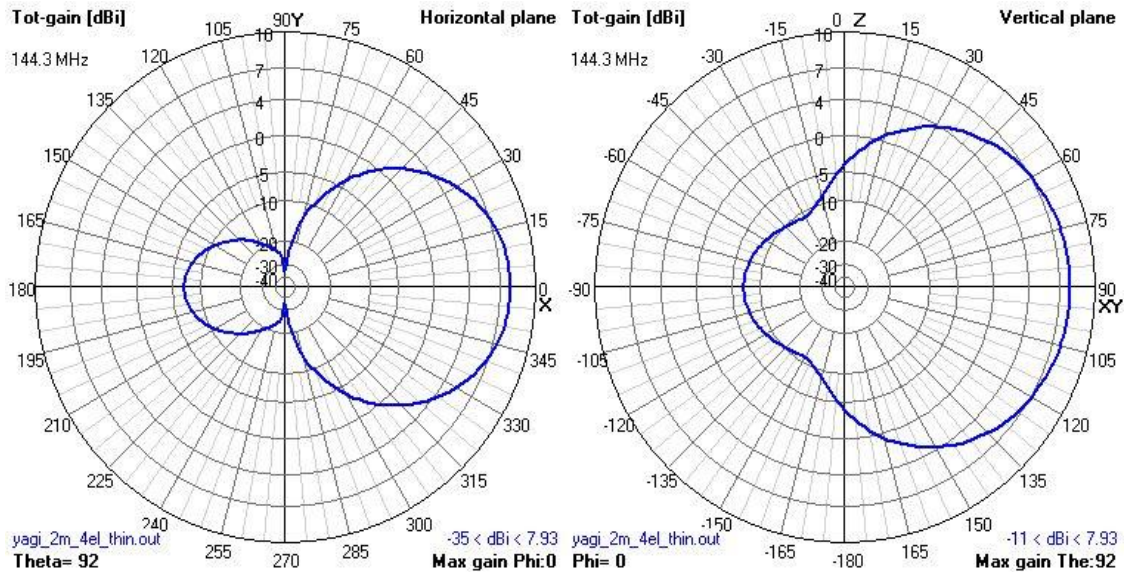
STACKING OF TWO OR MORE YAGIS TO GET MORE GAIN

- Additional gain and directivity can be obtained by combining two or more Yagis to form an array.



YAGI FRONT/BACK RATIO

- Despite the focusing action of the reflector and director in a Yagi, a small amount is lost to the rear, making the Yagi a less than perfect directional antenna.
- Thus, in addition to the gain and beam width, another important specification the front-to-back (F/B) ratio.
- By varying the number of parasitic elements and their spacing, it is possible to maximize the F/B ratio.



APPLICATION OF YAGI ANTENNAS

- Yagi antennas are widely used communication antennas because of their directivity and gain.
- At one time, they were widely used for TV reception, but since they are tuned to only one frequency, they are not good for reception or transmission over a wide frequency range.
- **Class to discuss:**

1. What does the frequency on the Yagi antenna in the lab represent?
2. Why is its significance to a buyer in Kenya?

PARTII: ANTENNA ARRAYS

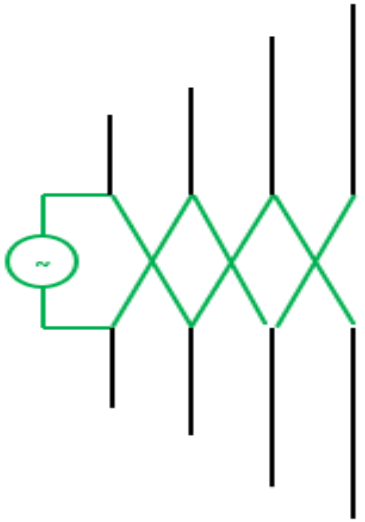
DRIVEN ANTENNAS

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TYPES OF DRIVEN ARRAYS

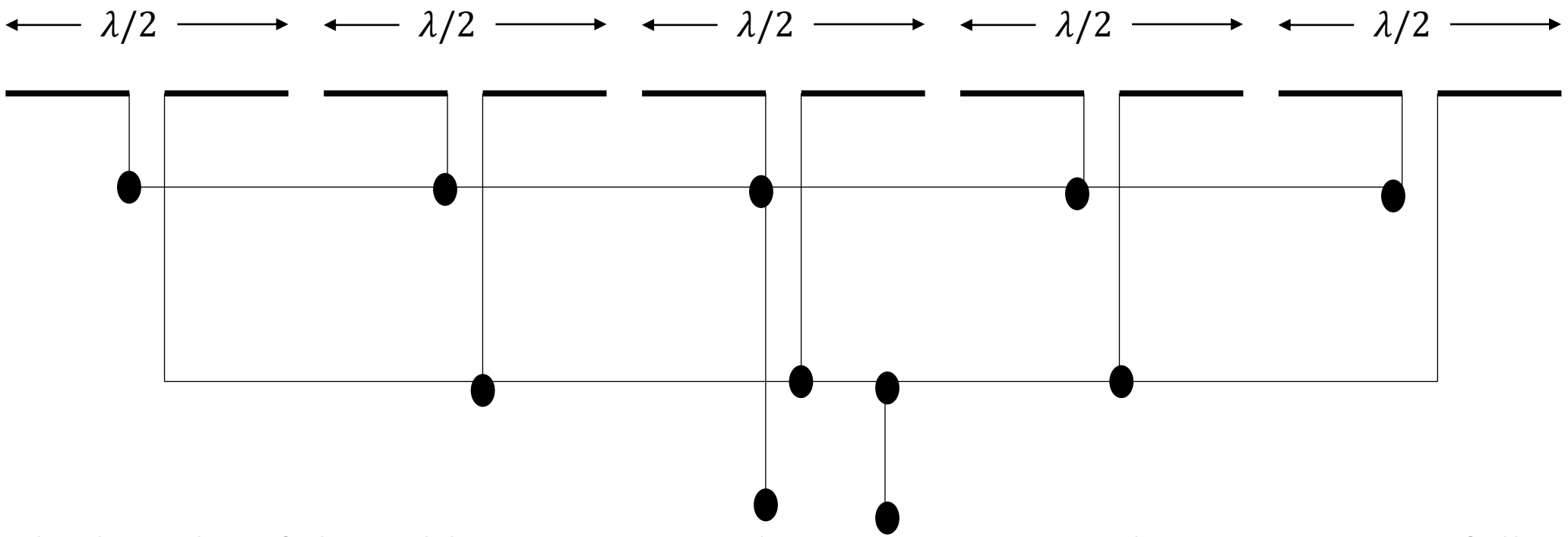
1. There are many types of driven arrays.
2. The four most common types are:
   a) Collinear array
   b) Broadside array
   c) Log Periodic Array



(b) Driven array

COLLINEAR ANTENNAS

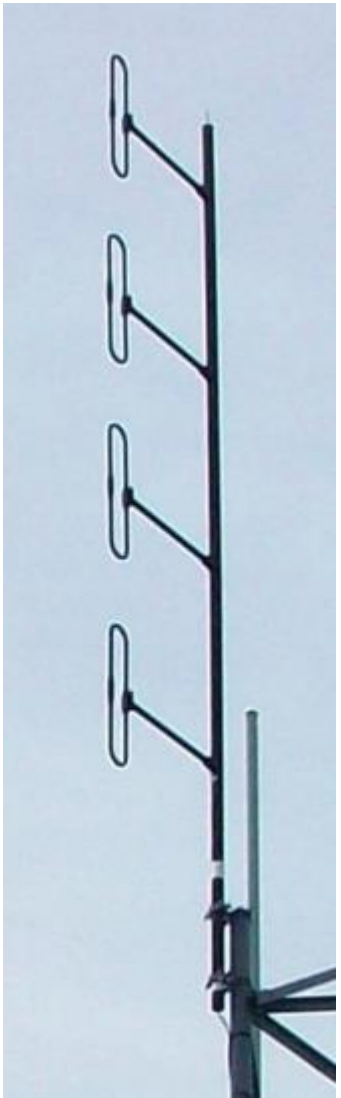
1. Collinear antennas usually consist of two or more halfwave dipoles mounted end to end.



2. The lengths of the cables connecting the various driven elements are carefully selected so that the energy reaching each antenna is in phase with all other antennas.
3. The individual antenna signals combine, producing a more focused beam.

COLLINEAR ANTENNA PRACTRICAL INSTALLATION

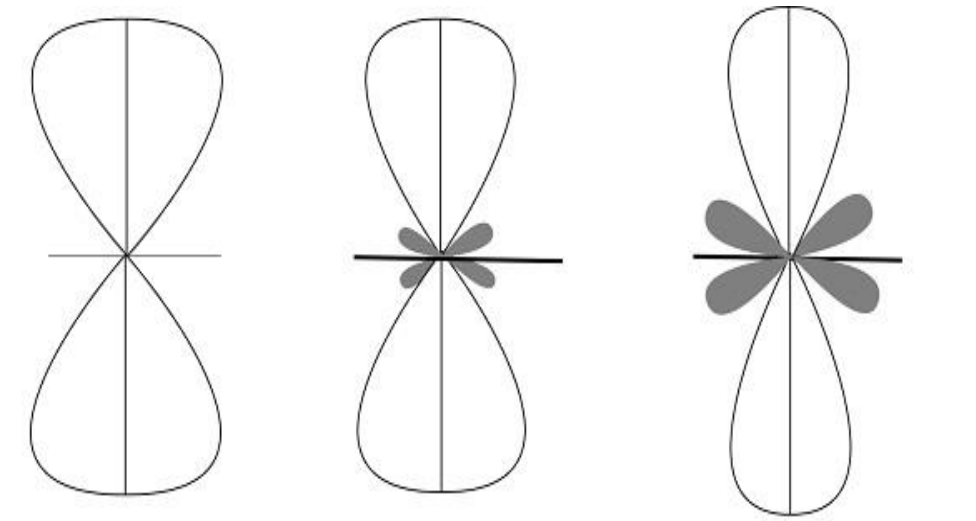




COLLINEAR ANTENNA RADIATION PATTERN

- Like dipole antennas, collinear antennas have a bidirectional radiation pattern, but the two beam widths are much narrower, providing greater directivity and gain.

- With four or more halfwave elements, minor lobes begin to appear.



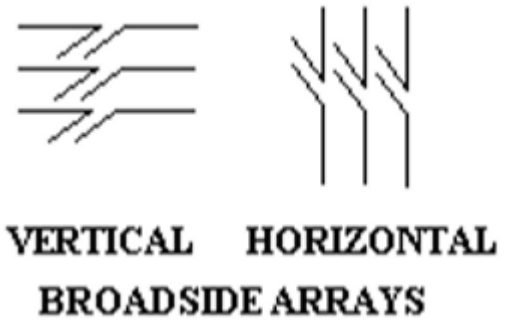
PATTERN WITH TWO ELEMENTS

PATTERN WITH THREE ELEMENTS

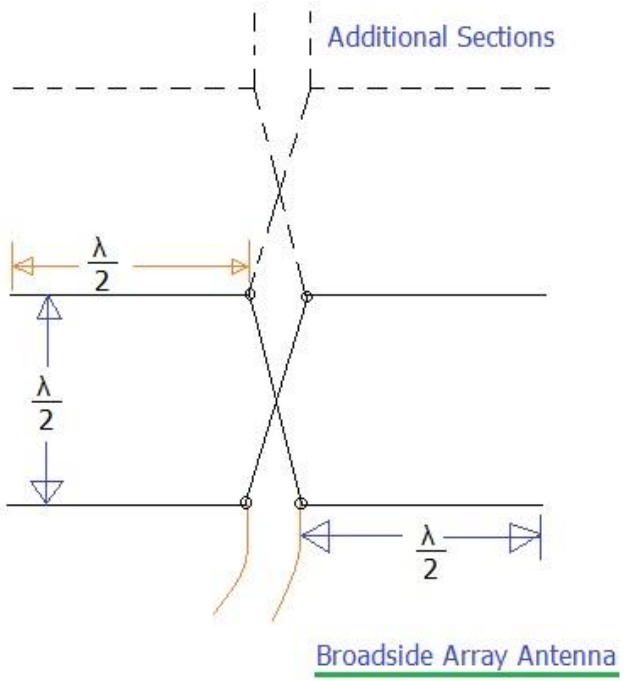
PATTERN WITH FOUR ELEMENTS

BROADSIDE ARRAY

- A **broadside array** consists of an array of dipoles mounted one above another as shown below.

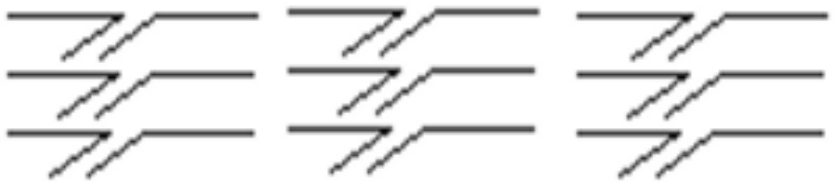


- Each dipole has its own feed line and the lengths of all feed lines are equal so that the currents in all the dipoles are in phase.



TWO DIMENSIONAL ARRAYS

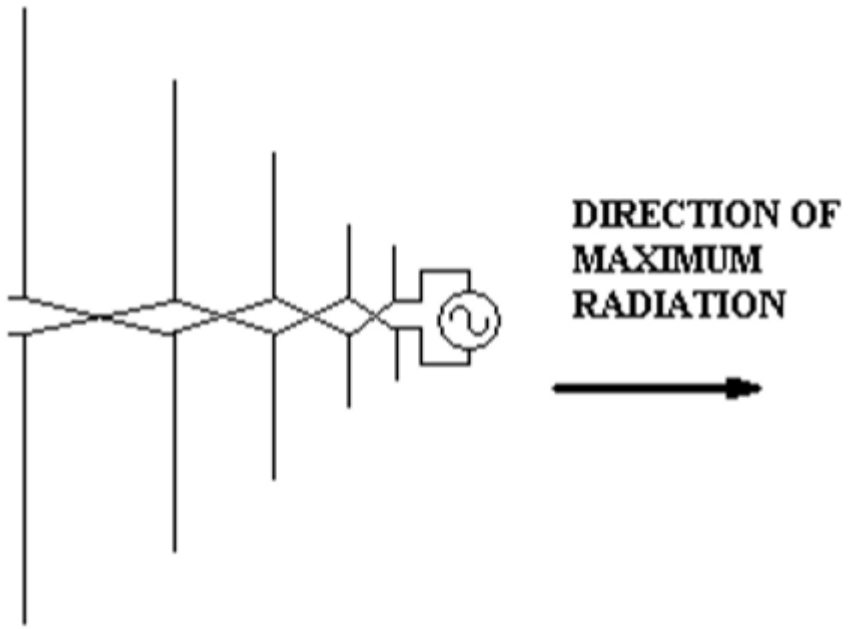
- **Two-dimensional array** is a 2D variation of the broadside array.
- It is used in high performance radar systems.
- The amplitude and phase of each input current is adjusted so that the antenna radiates its RF in a narrow beam.
- By making changes to the input phase and amplitude, the beam can be made to scan over a wide range of angles.
- Electronic scanning is much faster than mechanical scanning (which uses a rotating antenna) and permits rapid tracking of large numbers of targets.



TWO-DIMENSIONAL ARRAY

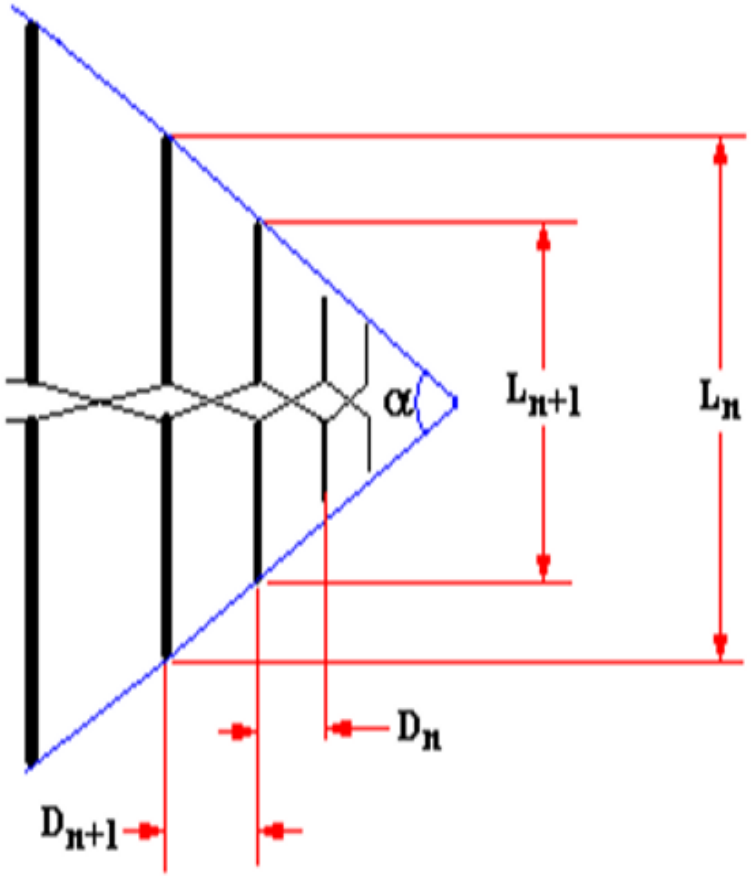
LOG PERIODIC DIPOLE ARRAY

- **Log-periodic antenna** is a broadband, multi-element, directional, narrow-beam antenna that has impedance and radiation characteristics that are regularly repetitive as a logarithmic function of the excitation frequency.
- The individual components are often dipoles.
- The lengths and spacings of the elements of a log-periodic antenna increase logarithmically from one end to the other.



LOG PERIODIC DIPOLE ARRAY

- The lengths of the driven elements vary from long to short and are related logarithmically.
- The longest element has a length of one-half wavelength at the lowest frequency to be covered,
- The shortest element is approximately one-half wavelength at the higher frequency.



$$L_N = \frac{500}{f_{MIN}} \qquad L_1 = \frac{360}{f_{MAX}} \qquad \sigma = \frac{1-\tau}{4\tan(\alpha)} \qquad \tau = \frac{D_n}{D_{n+1}} = \frac{L_n}{L_{n+1}}$$

APPLICATION OF LOG PERIODIC ANTENNAS

- The great advantage of the log-periodic antenna over a Yagi or other array is its **very wide bandwidth**.
- Most Yagis and other driven arrays are designed for specific frequency or a narrow band of frequencies. The lengths of the elements set the operating frequency. When more than one frequency is to be used, of course, multiple antennas can be used.
- The log-periodic antenna can achieve can have a bandwidth of an octave or more, giving it a very wide bandwidth. The driving impedance remains constant over this range.
- Some TV antennas in use today are of the log-periodic variety so that they can provide high gain and directivity on both VHF and UHF TV channels.
- Log- periodic antennas are also used in other two-way communication systems where wide bandwidth or multiple frequencies must be covered.