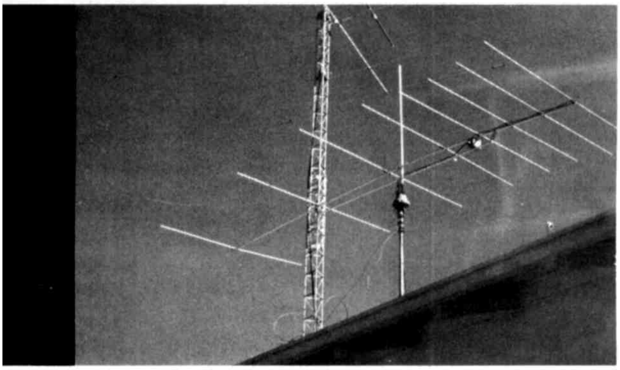

log-periodic yagi beam antenna

An adaptation of the Yagi array to obtain better bandwidth performance

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The Yagi parasitic beam antenna consists of a driven element plus a number of parasitic elements that increase the gain or directivity of the radiation pattern over that of a dipole antenna.[1] The number of parasitic elements, their tuning, and their spacing with respect to the driven element determine the characteristics of the array.

Generally speaking, the Yagi provides the greatest gain per unit size of any antenna array. Under normal circumstances, the more the elements, the greater the gain and the sharper the pattern of the Yagi. But as the number of elements increases, the more restricted will be the bandwidth of this popular antenna.

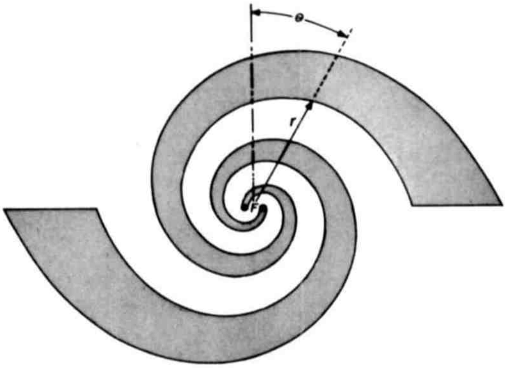
This bandwidth restriction, increasingly critical with respect to antenna gain, is of minor importance in the high-frequency bands, which are narrow, and where the Yagi is of modest size. However, antenna bandwidth becomes of paramount importance in the wider amateur bands where Yagi arrays are larger with respect to wavelength.

equiangular antenna concept

The restricted bandwidth of the Yagi beam may be improved by abandoning the parasitic element approach and applying instead equiangular principles. The equiangular principle deals with the design and assembly of frequency independent radiators. It is based on the unique idea that if the shape of an antenna can be specified entirely by angles, antenna performance would be independent of frequency.[2]

Practically speaking, this means that if all the dimensions of a radiator are scaled by a constant factor, the physical size of the antenna may be changed without changing any of its electrical characteristics, provided its operating wavelength is changed by the same amount.

fig. 1. Equiangular spiral antenna is symmetrical about feedpoint F and is described in terms of angle θ and radius r from polar axis.



A simple two-dimensional, equiangular spiral antenna that conforms to this requirement is shown in **fig. 1.**

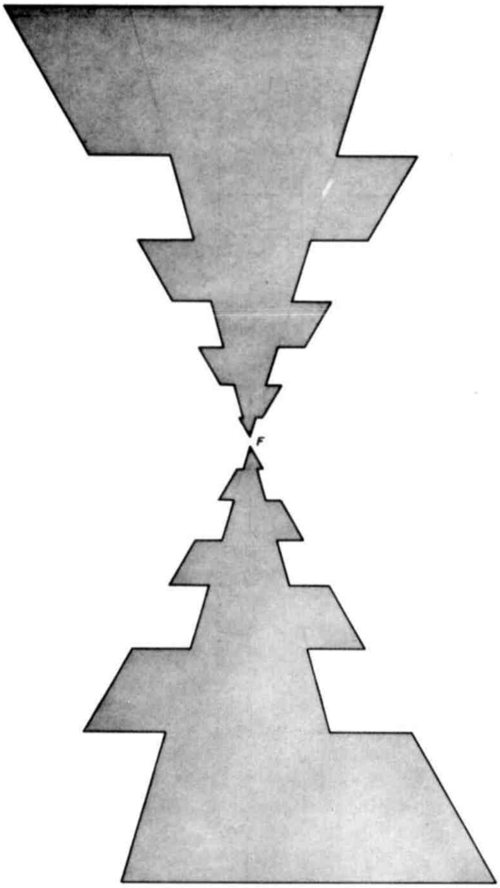
To be truly independent of frequency, the equiangular spiral antenna would have to start at an infinitely small point and expand to infinity. Practically, the antenna must have a feed point of finite dimension at the center and must have outer limits, as it cannot be infinite in size. Thus the frequency coverage of the structure is finite and is defined by physical, not electrical limitations.

Within the frequency limits imposed by these practical considerations, the equiangular spiral antenna resembles a frequency independent structure. This comes about because the transmission line is equivalent to the missing center portion of the structure, and the truncated outer portion does not affect the electrical properties to any significant degree. Most of the energy is radiated before it reaches the end of the structure if the antenna is large compared to the size of the radio wave.

the log-periodic antenna

The equiangular spiral antenna has limited use and exhibits little power gain over a dipole. A modification of the equiangular spiral antenna that provides power gain and directivity is shown in **fig. 2** wherein a planar structure is repeated periodically with respect to the logarithm of the frequency.[3] An antenna array of this configuration has characteristics that change with frequency, but before the change is very great in terms of wavelength, the structure **repeats itself**. A combination of the equiangular approach with the concept of periodicity results in a

fig. 2. Periodic planar antenna. Structures may be bent back upon themselves to form a three-dimensional array.



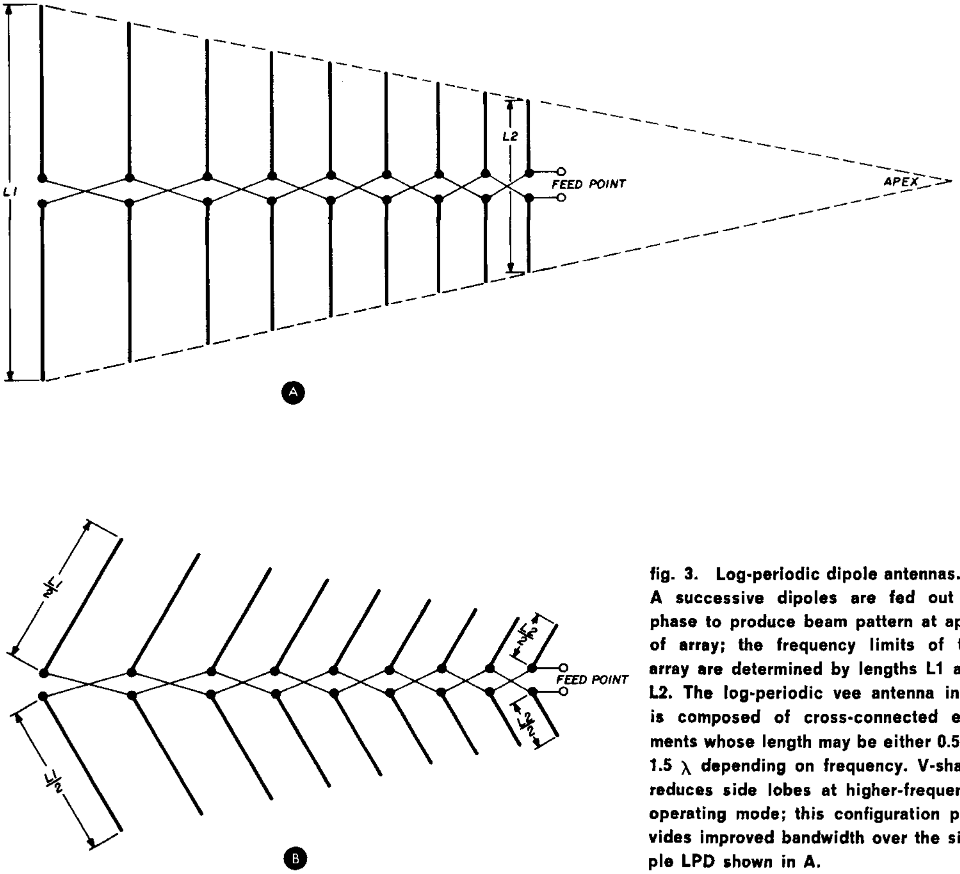


fig. 3. Log-periodic dipole antennas. In A successive dipoles are fed out of phase to produce beam pattern at apex of array; the frequency limits of the array are determined by lengths L1 and L2. The log-periodic vee antenna in B is composed of cross-connected elements whose length may be either 0.5 or 1.5 λ depending on frequency. V-shape reduces side lobes at higher-frequency operating mode; this configuration provides improved bandwidth over the simple LPD shown in A.

practical antenna with directivity and power gain and which has a bandwidth limited only by the antenna's physical size.

Various forms of the log-periodic antenna have been designed for specific uses. One of the most popular designs is the **log-periodic dipole** (LPD) array. The LPD antenna consists of a series of dipoles fed at the center and connected to the opposite wires of a balanced transmission line (**fig. 3**). The dipole lengths are consecutively shorter, and radio energy travels along the transmission line until it reaches a portion of the dipole structure where the length of the dipoles and their phase relationship combine to produce radiation.

The radiation is directed along the array toward the apex, so that the shorter elements either tend to act as directors or, if very short, are inactive. The LPD array can be fed at the apex with a balanced line, or with a balun and coaxial line. The antenna performs over a frequency span with limits defined by frequencies at which the extreme elements of the configuration are about one-half wavelength long. Antennas of this general type are commonly used for tv reception and are often used for amateur work at vhf.[4]

frequency limitations of the yagi

The Yagi parasitic beam functions as a directional antenna having power gain by virtue of the proper phasing of the parasitic elements. For high-frequency Yagi beams commonly used in amateur bands, the parasitic elements are spaced from the radiator by 0.15 to 0.25 wavelength and are about five percent longer or shorter than a half-wavelength, depending upon the function of the parasitic and the array spacing. Directivity is through the shortest parasitic element.

The number of parasitic elements also enters into the determination of optimum parasitic length, power gain, directivity, and bandwidth. Needless to say, as the operating frequency of the Yagi array is varied from the design frequency by a few percent, the parasitic elements become detuned from optimum, and over-all antenna gain drops sharply, especially when the parasitic elements become self-resonant. In some instances, depending on parasitic element tuning, the directional radiation pattern is obscured, or even reversed, with maximum gain occurring in the reverse direction of the array.

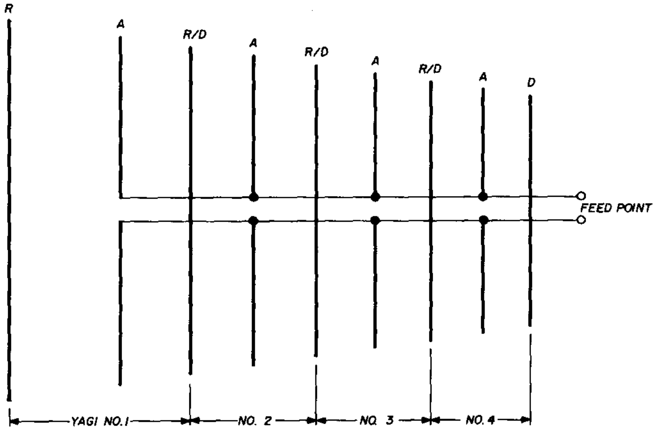


fig. 4. Log-periodic Yagi performance is a result of Yagi arrays with parasitic elements serving dual function of director and reflector for adjacent larger and smaller Yagi arrays.

Antenna power gain and beam directivity degeneration commonly occur when the parasitic element tuning is incorrect. Thus, the frequency span of the Yagi antenna must be restricted to that narrow region over which the parasitic elements remain in proper phase relationship. To increase the bandwidth of the Yagi, the parasitic elements must be detuned from optimum, which decreases power gain and reduces front-to-back ratio. The gain-bandwidth product of the Yagi must therefore be sacrificed to some extent to obtain an increase in either factor. In any case, the product is small but is a critical factor of adjustment. To increase the bandwidth without a corresponding decrease in gain, log-periodic principles may be applied to the Yagi antenna.

the log-periodic yagi

A log-periodic Yagi (LPY) array may be constructed of individual Yagi antennas differing in size by a geometric constant, properly arranged and fed. A simple LPY antenna is shown in **fig. 4.** The LPY is made of a series of end-fire Yagis, with each driven element fed from a common balanced transmission line. Unlike the driven element in an LPD antenna, those of the LPY are fed in a non-transposed manner. The in-between elements are parasitics, and log-periodic performance is obtained by making each parasitic element serve the dual function of director and reflector for the adjacent larger and smaller driven elements.

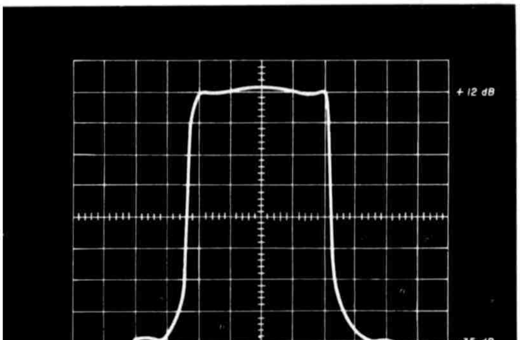
Practical LPY antennas with power gains of about 9 dB have been built for the 1.1- to 1.25-GHz range.[5] Over-all length of the LPY antenna is large for the gain produced, especially considering the high power gain per Yagi array normally obtained for a given size.

the bandpass antenna

An interesting and practical variation of the basic LPY antenna is the **LPY bandpass array**, which provides greater power gain per unit length. This unique antenna makes use of a log-periodic dipole structure having the frequency characteristic of a Chebyschev-type filter. A number of parasitic director elements, trimmed to cover the appropriate frequency range are used to enhance the power gain of the log-periodic array. A frequency sweep of such an antenna designed for the six-meter band is shown in the photograph. The LPY bandpass antenna is easy to build, simple to adjust, and provides good power gain considering the over-all length of the structure. The original LPY bandpass design was evolved for long-distance color-tv reception, which demanded a combination of good passband characteristics, high gain, and good adjacent channel discrimination. The LPY bandpass antenna combines these attributes, and various versions of this antenna are now used for tv and amateur two and six meter band operation. They are commercially available.*

An effective six-meter band LPY bandpass antenna is shown in **fig. 5** and the photo. It's composed of five log-periodic elements and three parasitic directors. The antenna has been in use for some months at K6RIL and at other California six-meter stations. Results compare favorably with an eight-element Yagi on a thirty-foot boom. Gain is estimated at 12 dB or better; front-to-back ratio is apparently about 24 dB. The design range is 50 to 52 MHz.

Response on reception is down about 20 dB at 47 and 53 MHz. It provides some receiver protection from spill-over from nearby channel-2 tv transmitters, because antenna response is down a comfortable number of decibels at frequencies higher than 54 MHz. Antenna response is down 20 dB at 45 degrees either side of center at 51 MHz. This is representative of the pattern over the antenna's operational range.



Gain-vs-frequency characteristic of the six-meter LPY antenna.

photo by W6BUR

Oliver Swan with a wideband 12-element 400 to 450 MHz antenna at the West Coast VHF Conference antenna-measuring contest; gain measured at approximately 7.5 dB.

Input impedance is about 75 ohms. The antenna can be fed with a 70-ohm coax line (RG-11A/U) and a balun, or a matching device can be placed at the antenna apex for use with a 50-ohm coax line or high-impedance balanced line. The line at K6RIL is 75-ohm heavy-duty tv ribbon.

construction

The commercial version of this antenna is built on a double boom, much in the manner of heavy-duty tv antennas (see

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* LPY bandpass antennas were originally designed by Oliver Swan and are for sale by Swan Antenna Company, 646 North Union Street, Stockton, California 95205.

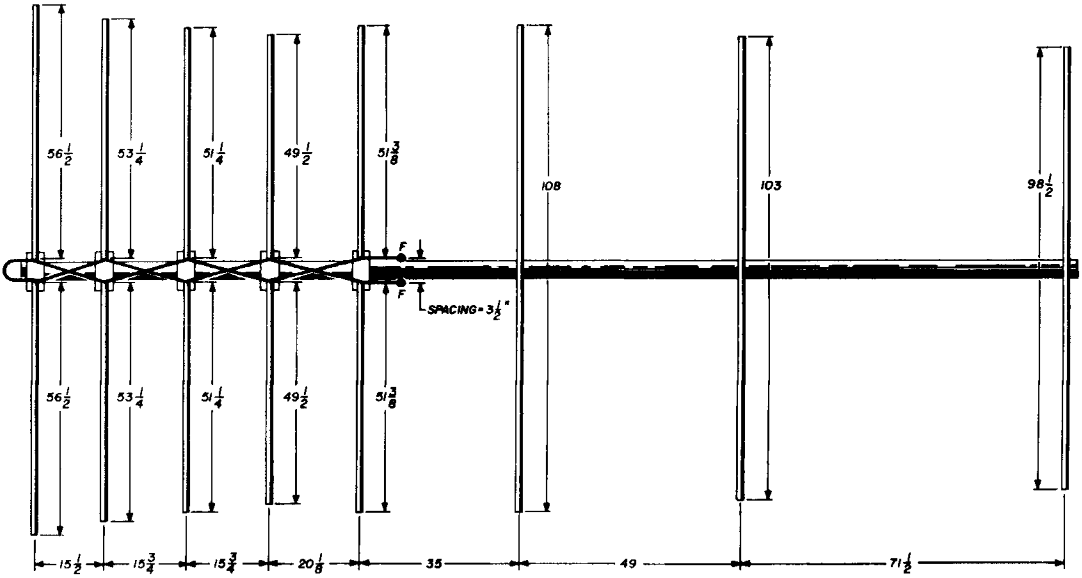

fig. 5. The LPY bandpass antenna. Dimensions (in inches) are for 6 meters (50 to 52 MHz) although they may be scaled for other frequency ranges. Elements are supported above a 2-inch aluminum boom. Half lengths are given for the log-periodic elements and full lengths for the parasitic elements.

photograph). A simpler configuration for those wishing to build their own array would be the use of sections of 2-inch aluminum tubing for the boom, as shown in **fig. 5.** The driven elements are supported at the center on insulating blocks, and the parasitic elements are mounted directly to the metal boom. Since a simple log-periodic structure is used with no interspersed parasitics, the driven elements are cross-connected with aluminum clothesline wire. The last driven element to the rear is shunted with a six-inch loop of wire at the end of the transposed feedline.

A balanced feedpoint exists at the front of the log-periodic assembly, and a balun or matching device may be mounted at this point. The array is supported from the vertical mast structure at the array's center of gravity. An overhead support to each end of the boom is recommended.

operation

The LPY bandpass antenna has been in operation at K6RIL for some months and is used in conjunction with an eight-element Yagi on a thirty-foot boom, mounted on a nearby tower. Numerous tests on transmission and reception have shown that the two antennas are nearly identical in performance as far as gain and front-to-back ratio are concerned, within the bandpass of the Yagi antenna. Operation of the LPY bandpass antenna at the extremes of the passband shows superior performance compared to the Yagi. The LPY bandpass array will be the "antenna to watch" on two and six meters in the coming months.

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