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NEW TYPES OF YAGI-UDA ARRAYS AND LOG-PERIODIC ANTENNAS

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1. Introduction

Directivity with antennas in the VHF- and UHF-range is very often achieved by combining straight-lined dipoles within an array. Among the most popular concepts are the Yagi-Uda array and the log-periodic array. It is difficult with both types of antennas, however, to exceed certain limits of gain, unless very bulky constructions are tolerable. This is mainly due to the fact that the directivity of the individual straight-lined dipole elements is limited to 2-4 dB depending on their electrical lengths. It is the aim of this contribution to show that Yagi-Uda arrays and log-periodic antennas can be built, which show either higher gain at constant antenna size or identical values of gain with reduced size, if optimum-shaped instead of straight-lined dipoles are used.

2. Gain-optimized single radiator

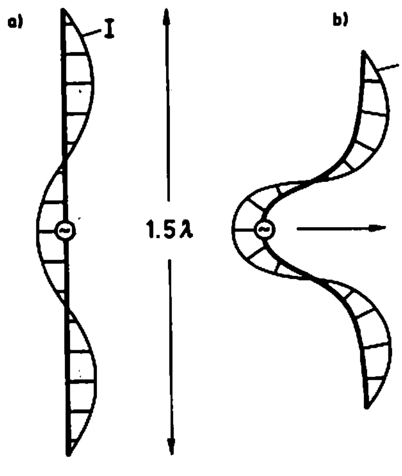


Fig. 1 First order current distribution
a) straight-lined dipole
b) optimum-shaped dipole

Fig. 1a shows a first approximation of the current on a straight-lined 1.5 λ-dipole. From the phase reversal within the current distribution it becomes evident that radiation normal to the dipole axis will be poor. On account of this fact, dipoles considerably longer than one wavelength are scarcely used.
If properly shaped, however, as shown in Fig. 1b, a 1.5 λ-dipole can be a very efficient radiator. The gain as measured with the shape of Fig. 1b, e.g. is around 7.8 dB. The special form of this antenna was found by means of an optimization program which is described elsewhere /1/. Due to the curved shape, the individual elementary waves, originating at the current elements on the dipole, travel different distances to a far-away point in the direction of main radiation. Hence the phase differences within the current distribution can nearly be compensated by the phase-shifts caused by the different path lengths.
The same optimization technique as used for the antenna of

Fig. 1b can be applied to a dual-wire structure; the optimum shape is given in Fig. 2. Due to the fact that the dipole also extends into the H-plane, the gain of this antennas is still higher than that of the single-wire dipole. It was measured around 10.5 dB with respect to the isotropic radiator. The input impedance ist around 70 Ohms at resonance, that of the single-wire radiator close to 170 Ohms.

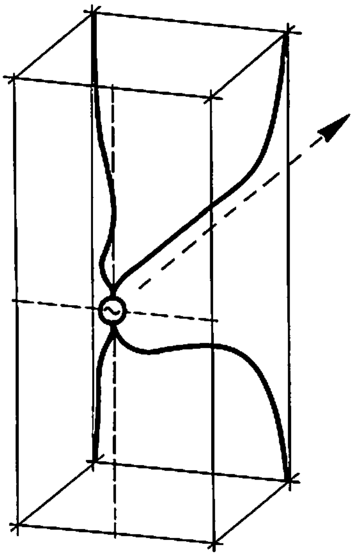


Fig. 2 Optimized dual-wire dipole

3. Yagi-Uda array with optimized elements

As the antennas described in chapter 2 show values of gain which are considerably higher than those found with conventional straight-lined dipoles, it seems promising to use these optimized structures within the configuration of a Yagi-Uda array. Fig. 3 shows a 3-element array of this type. The central radiator is fed and its shape corresponds to that of Fig. 1b. Reflector and director have been shaped with empirical methods on the principle of an approximately uniform distribution of the radiation coupling i.e. roughly constant distance between main radiator and adjacent parasitic elements. Fig. 4 shows the E-plane radiation pattern for this antenna. Its gain was measured at 11.5 dB with a sidelobe attenuation greater than 20 dB and a front-to-back ratio around 26 dB. The dimensions of this antenna are considerably smaller than those of a conventional array with the same gain, at the sacrifice of bandwidth , however. Typically, the relative bandwidth of the new array is 8 % if a reduction in gain of 3 dB at the band limits is tolerable. If the element of Fig. 2 is used in a similar 3-element array, the gain is around 13.6 dB.

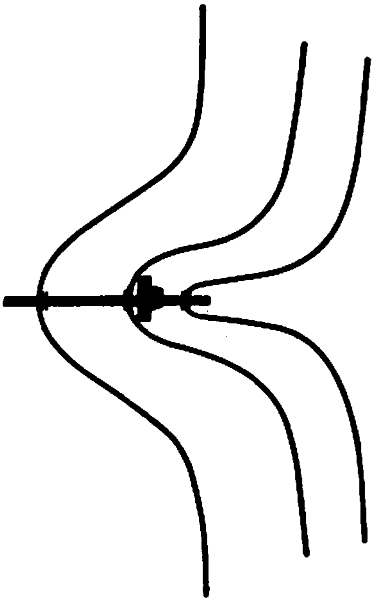


Fig. 3 Yagi-Uda array with optimized elements

4. Log-periodic antennas with optimized elements

If the radiators of Fig. 1 b and Fig. 2 are incorporated as elements in a logarithmic-periodic array, the broadband capabilities of the log-periodic principle are combined with

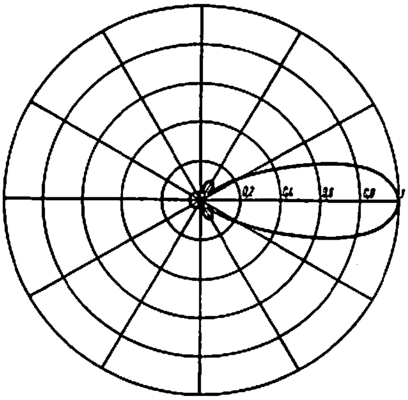


Fig. 4 E-plane pattern of the array of Fig. 3

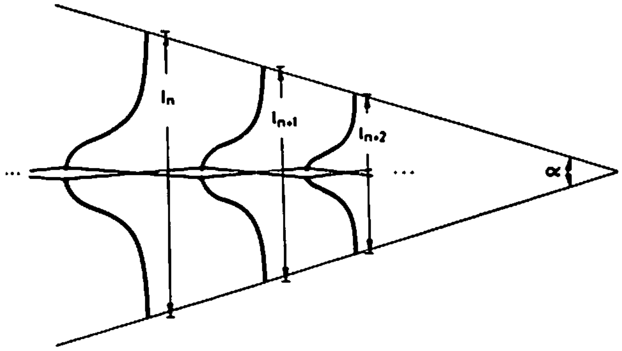


Fig. 5 Schematic view of a LP-antenna with optimized elements

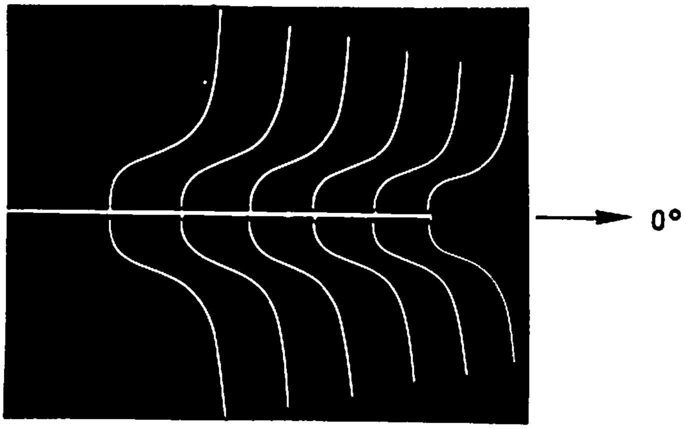


Fig. 6 LP-antenna with optimized elements

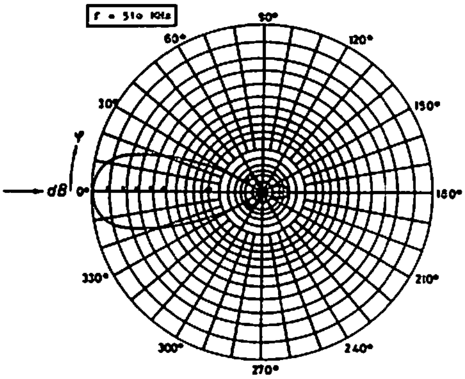
the high directivity of the optimized dipoles.
Conventional log-periodic antennas are generally described in terms of the flare angle α and the parameter τ . These parameters can also be applied to log-periodic arrays with optimum shaped elements as shown schematically in Fig. 5.

$$\tau = l_{n+1}/l_n$$

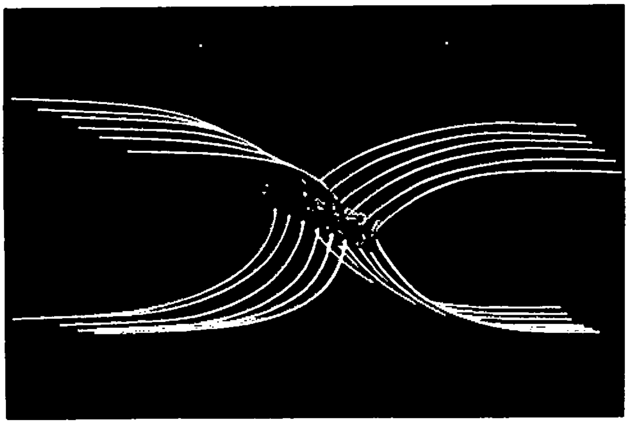
For antennas of the type shown in Fig. 5, the value of τ must be chosen carefully as the relative bandwidth b_{rel} of the gain-optimized elements is smaller than that of a conventional dipole.
Favourable results have been obtained with

$$\tau \approx 1 - b_{rel}.$$

The flare angle may be chosen arbitrarily. As a general rule, small values of α give high values of gain at the expense of an increasing number of elements needed for a specified frequency range.
As an example, Fig. 6 shows a 6-element log-periodic array with optimized elements for the



<u>Fig. 7</u> E-plane pattern of the array of Fig. 6



<u>Fig. 8</u> LP-array with optimized dual-wire elements

frequency range 470 to 610 MHz. The average gain is around 12.5 dB with $\tau = 0.94$ and $\alpha = 20^{\circ}$. A typical E-plane radiation pattern for this antenna is given in Fig. 7. An array similar to that of Fig. 6 but with only 3 elements, covering the frequency range from 370 to 470 MHz, showed an average gain of 12.5 dB with $\tau = 0.87$ and $\alpha = 60^{\circ}$.

Log-periodic antenna arrays using the optimized radiator of Fig. 2 have been investigated intensively during the last months. Best results, as yet, have been obtained with the configuration of Fig. 8 and $\alpha = 40^{\circ}$, $\tau = 0.94$. The average gain measured over the frequency range from 470 to 610 MHz was in the order of 16 dB. Further experiments are under way.

<u>References</u>

/1/ Landstorfer, F.: On the optimum shape of linear antennas. IEEE Symp. AP, Amherst 1976, p. 167-172.

/2/ Landstorfer, F.: Optimization of the directivity of linear and horn antennas. Conf. on CAD of electr. and microwave circuits and systems. Hull U.K. 1977, p. 96..101.

/3/ Landstorfer, F.: Zur optimalen Form von Linearantennen. Frequenz 30 (1976). p. 344-349.