Sept. 9, 1969 P. E. MAYES ETAL 3,466,655

LOG PERIODIC DIPOLE ARRAY WITH DUAL BOND DIRECTORS

Filed Jan. 27, 1966

FIG. 1.

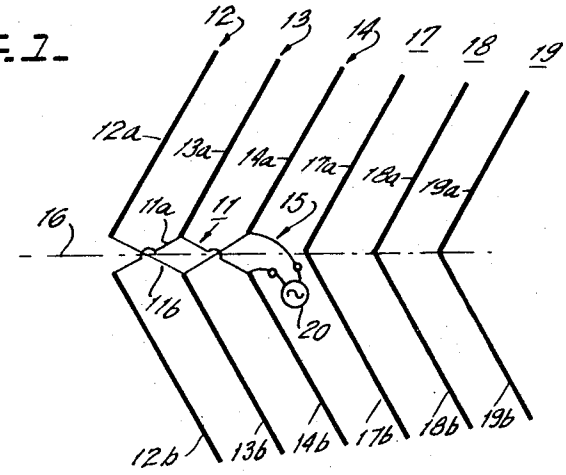
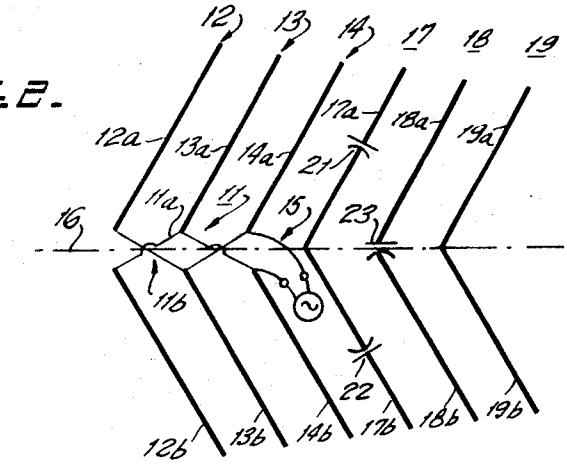


FIG. 2.



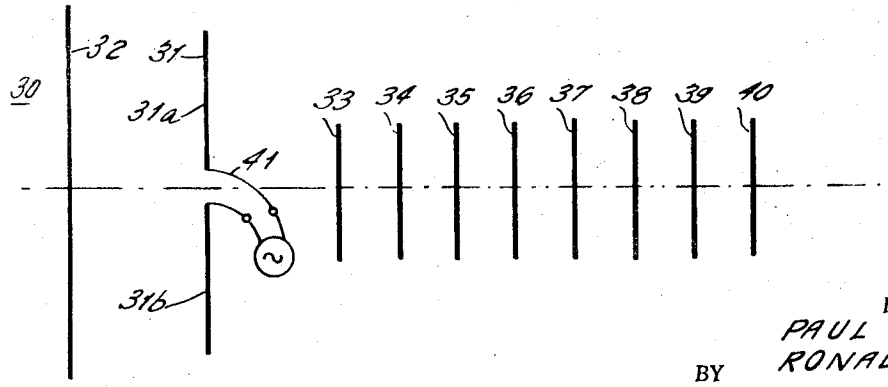


FIG. 3.

INVENTORS
PAUL E. MAYES
RONALD D. GRANT

BY

OSTROLENK, FABER, GERB & SOFFEN
ATTORNEYS

United States Patent Office

3,466,655

Patented Sept. 9, 1969

3,466,655

LOG PERIODIC DIPOLE ARRAY WITH DUAL BAND DIRECTORS

Paul E. Mayes, Champaign, and Ronald D. Grant, Urbana, Ill., assignors, by mesne assignments, to JFD Electronics Corporation, Brooklyn, N.Y., a corporation of Delaware

Filed Jan. 27, 1966, Ser. No. 523,447
Int. Cl. H01q 11/10
U.S. Cl. 343—792.5 6 Claims

ABSTRACT OF THE DISCLOSURE

An antenna array operating in both the VHF and UHF bands comprised of a dipole section arranged in log-periodic fashion and a director positioned in front of the forward end of the dipole section. The dipoles each have a tip-to-tip electrical length of one-half wavelength in the lower operating frequency range and further resonate at odd multiples of a half-wavelength. The directors each have an electrical length which is slightly less than three-halves wavelengths where the wavelengths are selected near the high end of the operating frequency range. The directors will further resonate at those odd multiples of a half-wave length which are greater than three-halves wavelengths.

The instant invention relates to antennas and more particularly to novel director means for providing high-gain in antennas of broad-band responsive characteristics.

Antennas having broad-band response characteristics are quite desirable for a variety of applications. For example, it is desirable to provide a single antenna array for use in receiving (or transmitting) both the low and high frequency television bands within the VHF frequency range. The television channels 2–6 lie in the band from 54–88 megacycles while channels 7–13 lie in the band VHF channel frequencies from 174–216 megacycles. Broad-band antenna structures which have successfully provided reception (or transmission) for both the low and high bands of the VHF channel frequencies may assume a variety of designs. One design which has proven successful is that of the log-periodic antenna array which is designed to resonate at a plurality of odd integral half wavelength modes so as to provide reception (or transmission) for both the low and high band VHF channel frequencies.

In many instances, such broad-band antennas lack adequate gain characteristics and one conventional approach which is employed to enhance the gain of the antenna is to provide parasitic elements in the array.

Conducting rod or tubular elements incorporated in the antenna array and which are not connected to the feed line of the antenna array are commonly used to increase the directivity and gain of the antenna. Such elements are commonly referred to as "parasitic" elements so as to distinguish them from the elements which are electrically connected to the antenna feed line. The latter elements are commonly referred to as "driven" elements.

Parasitic elements which are placed in front of the driven elements of the antenna array are commonly trimmed in length so as to resonate at a slightly higher frequency (approximately 5%) than the upper limit of the

frequency band of the antenna array. This trimming of the parasitic elements causes the phase of the current in the parasitic element to be such that the field produced by the parasitic element adds to that produced by the driven element in the direction proceeding from the driven element toward the parasite. Such parasitic elements are commonly referred to as "directors." A plurality of directors can be added to an antenna array to produce further increases in directivity and gain, although the increment in gain diminishes as the number of directors increases beyond a predetermined number.

It has been conventional practice to employ directors having electrical lengths which are slightly less than one-half wavelength of the operating frequency. The phase of the induced current in the director element is controlled by the deviation of the element length from the resonant length which, in the case of a director element, can be adjusted to contribute to the electromagnetic field in the forward direction and detract from the electromagnetic field in the backward direction and thereby enhance directivity of the antenna array.

At operating frequencies near the high end of the VHF rage and at UHF frequencies and above, elements which are longer than one-half wavelength are of a practical and usable length. Such longer director elements will contribute to the directivity and gain to an increased degree. Proper phasing of these elements can be achieved by operating the director elements at frequencies slightly below the second or higher order resonant modes for the director.

It is therefore a primary object of the instant invention to employ parasitic elements which are considerably longer in electrical length than one-half wavelength in their tip-to-tip developed length in order to achieve significant increases in directivity and gain for antenna array.

The instant invention is comprised of an antenna useable over either a broad or narrow band having an array of driven elements which are designed to provide good reception (or transmission) over a predetermined range of operating frequencies. The antenna array is further provided with at least one parasitic element having an electrical length which is slightly less than an odd-integer multiple of one-half the operating wavelength in total developed tip-to-tip length. Alternately stated, the parasitic elements employed in the instant invention are most effective in increasing directivity and gain for the antenna array when they are operated at a frequency slightly below a higher order of resonance of the dipole. The resonant length is selected so that the second or higher order resonant mode for the parasitic element lie near the high end of the frequency band to be covered and preferably slightly higher than the highest frequency of operation of the antenna. The parasitic dipole may be comprised of a simple conducting rod or tube element whose tip-to-tip length is appropriately selected so as to be resonant at a second or higher order resonant mode which is preferably slightly higher than the highest frequency of operation of the antenna array. Since resonances above the lowest order resonating mode become the operating resonances of the parasitic elements, the dipole halves are preferably inclined with respect to one another forming a V-dipole configuration in order to optimize the forward gain and hence the directivity of the antenna. Although the director ele-

ments are designed to operate near the second or higher order resonant modes the lengths of these parasitic elements, even when used in the upper part of the VHF frequency band are still of a practical length so as to provide an antenna which avoids the possible mechanical problems in the design and support thereof. In cases where it is desired to shift the operating frequencies of the director elements employed, reactive elements may be added at the ends of the director dipole arms or along the length thereof so to provide director elements which have shifting electrical lengths for different operating frequencies.

It is therefore a primary object of the instant invention to provide an antenna having enhanced gain and directivity characteristics.

Still another object of the instant invention is to provide an antenna comprising director elements having electrical lengths greater than one-half wavelength within the operating frequencies of the antenna to achieve increased directivity and gain for the antenna array.

Another object of the instant invention is to provide a novel antenna array having enhanced gain and directivity characteristics and being comprised of at least one director element having an electrical length which is selected to operate the director element at slightly below the second or higher order resonant mode of the element.

Another object of the instant invention is to provide a novel antenna array having enhanced gain and directivity characteristics and being comprised of at least one director element having an electrical length which is selected to operate the director element at slightly below the second or higher order resonant mode of the element and wherein the director element is further comprised of reactive elements for shifting the resonant frequency of the director element.

Still another object of the instant invention is to provide a novel antenna array having enhanced gain and directivity characteristics and being comprised of at least one director element having an electrical length which is selected to operate the director element at slightly below the second or higher order resonant mode of the element wherein the director element arms are inclined with respect to one another in order to optimize forward gain for the antenna array.

These and other objects of the instant invention will become apparent when reading the accompanying description and drawings in which:

FIGURE 1 is a schematic diagram showing an antenna of log-periodic design employing the director elements of the instant invention.

FIGURE 2 is a schematic diagram showing an alternative embodiment for the antenna array of FIGURE 1.

FIGURE 3 is a schematic diagram showing a conventional Yagi antenna shown for the purpose of describing the advantages of the instant invention.

Referring now to the drawings, FIGURE 1 shows an antenna **10** which is comprised of a transposed feeder line **11** having electrically coupled thereto arms **12***a*–**14***a* and **12***b*–**14***b* forming the dipoles **12**–**14**, respectively. The arms of dipoles **12**–**14** are longest toward the left-hand end of the array and decrease in length gradually toward the right-hand end thereof. The take-off point **15** for the power, generally designated by the symbol **20** is electrically coupled to the transposed feeder harness **11** and may be a power source (transmitter) or sink (receiver), depending upon the particular application. In the preferred construction the spacing between adjacent driven dipoles measured along the longitudinal axis of the antenna represented by the phantom line **16**, decreases in a gradual manner from the left-hand toward the right-hand end of the antenna array. The length of the antenna arms **12***a*–**14***a* and **12***b*–**14***b* and the spacing between adjacent dipoles may typically be determined in the manner set forth in U.S. Patent No. 3,108,280 entitled "Log-Periodic Backward Wave Antenna Array," issued to Mayes et al. and assigned to the University of Illinois Foundation.

Such log-periodic design yields an antenna array which provides constant gain characteristics over a wide range of frequencies. It is preferable that the antenna be symmetrical about the phantom line **16** passing through the midpoints of the dipoles **12**–**14** and directors **17**–**19**, to be more fully described. The dipoles **12**–**14** are preferably bent or inclined in a V-configuration to enhance directivity of the antenna array when the dipoles are resonant in a higher order mode ($3\lambda/2$, $5\lambda/2$, etc.).

When acting as a transmitting antenna, the antenna is fed at its narrow end from a conventional source of energy, depicted in FIGURE 1, by way of illustration only, as alternator **20** which feeds the antenna by means of the balanced feeder line **11** consisting of conductors **11***a* and **11***b*. It can be seen that the conductors **11***a* and **11***b* are crossed over one another between connections to consecutive or adjacent elements of the antenna to provide a transposed feeder arrangement which greatly enhances the antenna front-to-back gain ratio as is well known in the prior art, thereby providing unidirectional response.

Although this type of driven section for the antenna array provides excellent performance, the instant invention is in no way limited with respect to the array of driven elements employed and may be employed to equal advantage with a driven section of another design. The explicit example shown herein is merely presented for purposes of clarification of the manner in which the parasitic elements of the present invention may be employed.

The parasitic elements **17**, **18** and **19** are comprised of arms **17***a*–**19***a* and **17***b*–**19***b*, respectively. Each of these arms may be separate conducting rods or tubes which are electrically connected at the inner ends and mechanically mounted along the antenna center line **16** in a V-configuration to provide optimum forward gain for the antenna array. If desired, the director elements **17**–**19** may be single straight elements which are bent at the longitudinal axis **16** for the antenna array **10** so as to provide the V-configuration. As can clearly be seen, none of these director elements are electrically connected to the feeder line **11** and hence form the parasitic section for the antenna array.

Although three such V-dipole directors **17**–**19** are shown in FIGURE 1, any number may be employed to advantage. The important criteria for operation of the parasitic directors in the higher order modes is to adjust the second (or other higher resonant frequency modes of the elements to fall near the high end of the frequency band to be covered and preferably slightly higher than the highest frequency of operation of the antenna. This may be done with either a simple conducting rod or tubular element by appropriate selection of the developed tip-to-tip length of the director element.

The principal advantages of the instant invention over conventional methods lie in the increased directivity and gain which the antenna array yields through the use of the director elements. To illustrate by means of one application, consider the design of an antenna to cover the band of frequencies between 800–900 megacycles which is used for the translator stations in UHF television broadcasting. The driven section of the antenna array comprised of the dipoles **12**–**14** may be designed in accordance with the formula set forth in the above mentioned U.S. Patent 3,108,280. Let it be assumed that it is desired to operate the driven elements to resonate at the $3\lambda/2$ mode. This means that the electrical length of the dipoles from tip-to-tip will be approximately 21 inches. This length is the developed length of the dipole which is the length which the dipole would be if it were a straight dipole, i.e., before it is arranged in a V-configuration. At a frequency of 800 megacycles λ is equal to approximately 14.6 inches and hence $3\lambda/2$ is equal to approximately 21.9 inches. At a frequency of 890 megacycles λ is equal to 13.2 inches and hence $3\lambda/2$ is equal to approximately 19.8 inches. Hence the electrical lengths of the driven dipoles **12**–**14** will approximately lie between 19.8 and 21.9 inches. The

spacings between the driven elements **12–14** may be established in accordance with the equations set forth in the above mentioned U.S. patent, or in any other well known fashion.

In order to select the lengths of the parasitic elements **17–19**, the second or higher order resonant mode of the driven elements should be near the upper end of the operating frequency range for the antenna **10** and preferably slightly higher than the highest operating frequency for the array. The tip-to-tip developed length for the director element **17**, for example, would be approximately 19.5 inches. The remaining dipole directors **18** and **19** would also be of nearly the same tip-to-tip developed length. Elements of these lengths pose no mechanical problems in the construction of such an antenna while the beam width of a typical dipole of this size is considerably less than that of a dipole operating at the $\lambda/2$ resonant mode, thus greatly enhancing the directivity and gain for the antenna array.

If it is desired to operate the director elements at higher resonant modes, for example, at $5\lambda/2$ resonant mode, the tip-to-tip length for the director element would be approximately 32.5 inches, which length likewise poses no mechanical problems for the construction of such antennas and which yields an even higher gain per element for the antenna array.

The parasitic elements **17–19** may be constructed of any good electrical conductors such as aluminum, copper, silver, gold, brass, just to name a few. The spacing between director elements when multiple directors are used may be uniform or may be variable within limits. Generally, the spacing between the first director element **17** and the adjacent driven element **14** will be different from the spacing between the first director element **17** and the subsequent director elements.

If it is desired to shift operating frequencies for the director elements this may be done in the manner shown in FIGURE 2. In the embodiment **10'** of FIGURE 2, it can be seen that this arrangement is substantially identical to the antenna array **10** of FIGURE 1 except that the director element **17** has been provided with reactive members **21** and **22** in the arms **17***a* and **17***b*, respectively, and director element **18** has been provided with a reactive element **23** located at the apex of the arms **18***a* and **18***b* and is electrically coupled to these arms. In the arrangement of director element **17** or of director element **18** the reactive elements **21–22** and **23**, respectively, alter the resonant frequency of the directors. The reactive component **23** likewise operates in a similar manner. The reactive components may either be capacitive, inductive, or a combination thereof, depending only upon the objectives of the user. A detailed description of the specific manner in which the reactive components are selected as to their values and are located along the director element arms is set forth in detail in copending application Ser. No. 414,975, entitled "Multiple Mode Operational Antennas Employing Reactive Elements," filed Dec. 1, 1964 by Grant et al. and assigned to the assignee of the instant invention.

To illustrate the superiority of the antenna array described herein when compared with conventional methods, consider the conventional design shown in FIGURE 3. The antenna array **30** of FIGURE 3 is a Yagi antenna employed for use in the translator frequency band of 800–890 megacycles. The Yagi antenna configuration **30** is provided with a single driven element **31** having dipole arms **31***a* and **31***b*. A single parasitic element **32** serves as a reflector and the elements **33–40** serve as directors. The driven element **31** is operated near the first resonant mode, i.e., the $\lambda/2$ resonant mode in order to provide a resistive input impedance to match the transmission line **41**. The reflector element **32** is of an electrical length which is slightly longer than the driven element and the directors are slightly shorter than the driven element **31** to provide the proper phasing for currents induced within the elements. Hence, all elements of the Yagi antenna are approximately one-half wavelength in tip-to-tip dimension. At the UHF translator frequencies this length is approximately seven inches. In order to achieve the high-gain, which is very desirable at these frequencies, it is necessary to use a very large number of directors. This leads to an antenna which may be six or seven feet long and only seven inches wide. Furthermore, after adding a few director elements the increment in gain which is achieved by adding each additional director becomes quite small. It can therefore clearly be seen that a comparison of the conventional design antenna **30**, shown in FIGURE 3, with an antenna array employing the director elements of the instant invention, that gain and directivity characteristics are quite superior through the use of the design of the instant invention, while the antenna array is much simpler and does not provide the mechanical problems which are confronted through the design of the Yagi antenna of FIGURE 3.

It can therefore be seen from the foregoing that the instant invention provides an antenna array employing director elements which are substantially longer than the director elements of conventional practice so as to greatly enhance the directivity and gain characteristics for the resulting antenna array.

Although there has been described a preferred embodiment of this novel invention, many variations and modifications will now be apparent to those skilled in the art. Therefore, this invention is to be limited, not by the specific disclosure herein, but only by the appended claims.

What is claimed is:

1. An antenna array comprised of:

a driven section having a plurality of dipoles;

a transposed feeder line for electrically coupling all of said dipoles;

said dipoles being spaced relative to one another and each having electrical lengths of odd multiples of a half-wavelength selected to operate said array in log-periodic fashion over a substantially broad frequency range;

the dipoles of greater electrical length being located toward the rear of said driven section and the dipoles of shorter electrical length being located toward the front of said driven section;

at least one director element being positioned in front of said driven section;

said director element having a tip-to-tip electrical length l, where l is slightly less than $(2n+1)\lambda/2$; where n is any non-zero integer; and where λ is the wavelength for a frequency at the high end of the operating frequency range, the length of said director element being less than the length of the shortest dipole.

2. The array of claim **1** wherein said director element is comprised of first and second sections symmetrically arranged about said longitudinal axis;

said sections being aligned to form a V-configuration with said sections being directed substantially toward the front of said array.

3. The array of claim **1** wherein said director element is comprised of first and second sections and is further provided with at least one reactive element electrically coupling said sections;

said reactive element being positioned intermediate the tips of said director element;

said reactive element being provided for shifting the resonant frequencies for said director element.

4. The array of claim **1** wherein a plurality of director elements are provided; each of said director elements being comprised of first and second sections symmetrically arranged about said longitudinal axis;

said sections being aligned to form a V-configuration with said sections being directed substantially toward the front of said array.

5. The array of claim 4 wherein at least one of said director elements is provided with at least one reactive element electrically coupling said sections;

said reactive element being positioned intermediate the tips of said director element;

said reactive element being provided for shifting the resonant frequencies for said director element.

6. The array of claim 4 wherein at least one director element is provided with first and second reactive elements each being positioned along an associated element section intermediate the longitudinal axis of said array and the tip of the associated section for shifting the resonant frequencies of said one director element.

References Cited

UNITED STATES PATENTS

3,371,348	2/1968	Simons	343—815
Re. 25,604	6/1964	Greenberg	343—792.5
2,485,138	10/1949	Carter	343—915 X
2,492,354	12/1949	Busignies	343—854
2,644,091	6/1953	Middlemark	343—819 X
2,789,286	4/1957	Marshall	343—815
2,980,912	4/1961	Anderson	343—815

ELI LIEBERMAN, Primary Examiner

U.S. Cl. X.R.

343—815