United States Patent

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[54] **MODULATED IMPEDANCE FEEDING SYSTEM FOR LOG-PERIODIC ANTENNAS**
9 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **343/770,** 343/792.5, 343/809, 343/862
[51] **Int. Cl.** **H01q 11/10**
[50] **Field of Search** 343/792.5, 811–817, 770, 809, 862

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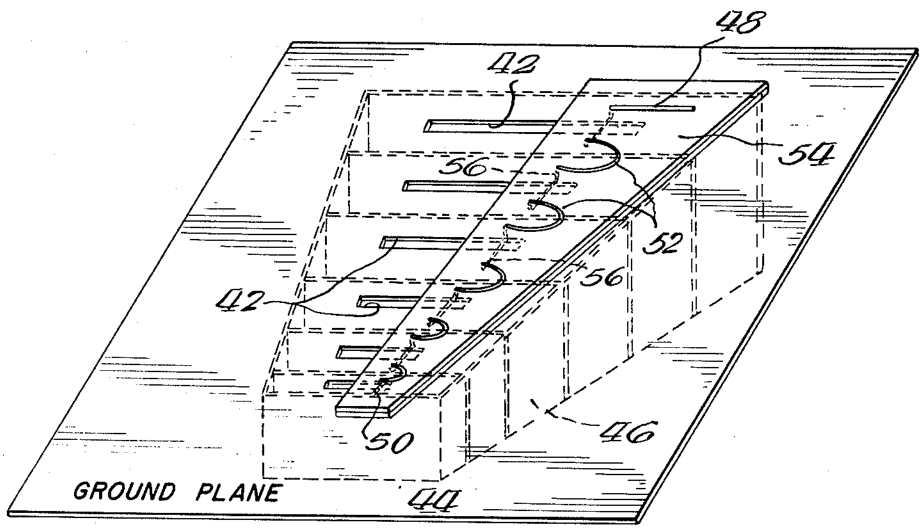
ABSTRACT: A modulated impedance feeding system for log-periodic antennas including loading elements, a transmission line to couple energy to or from the elements, and impedance-modulating means for matching the image impedances of the transmission line and the loading elements in the regions of local reflections to realize essentially frequency independent performance. A log-periodic monopole array and a cavity backed slot array are provided, fed with a modulated impedance meandering line according to the invention. A log-periodically scaled directional coupler feed line for antenna arrays is provided, including in one embodiment thereof a coupler fed, log-periodic resonant V array.



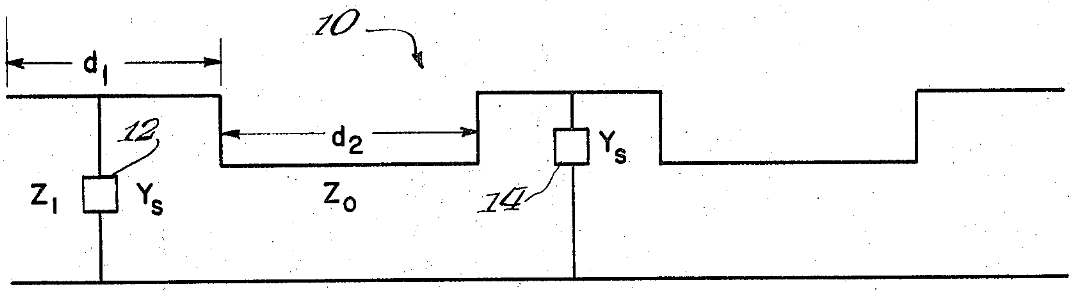


Fig. 1

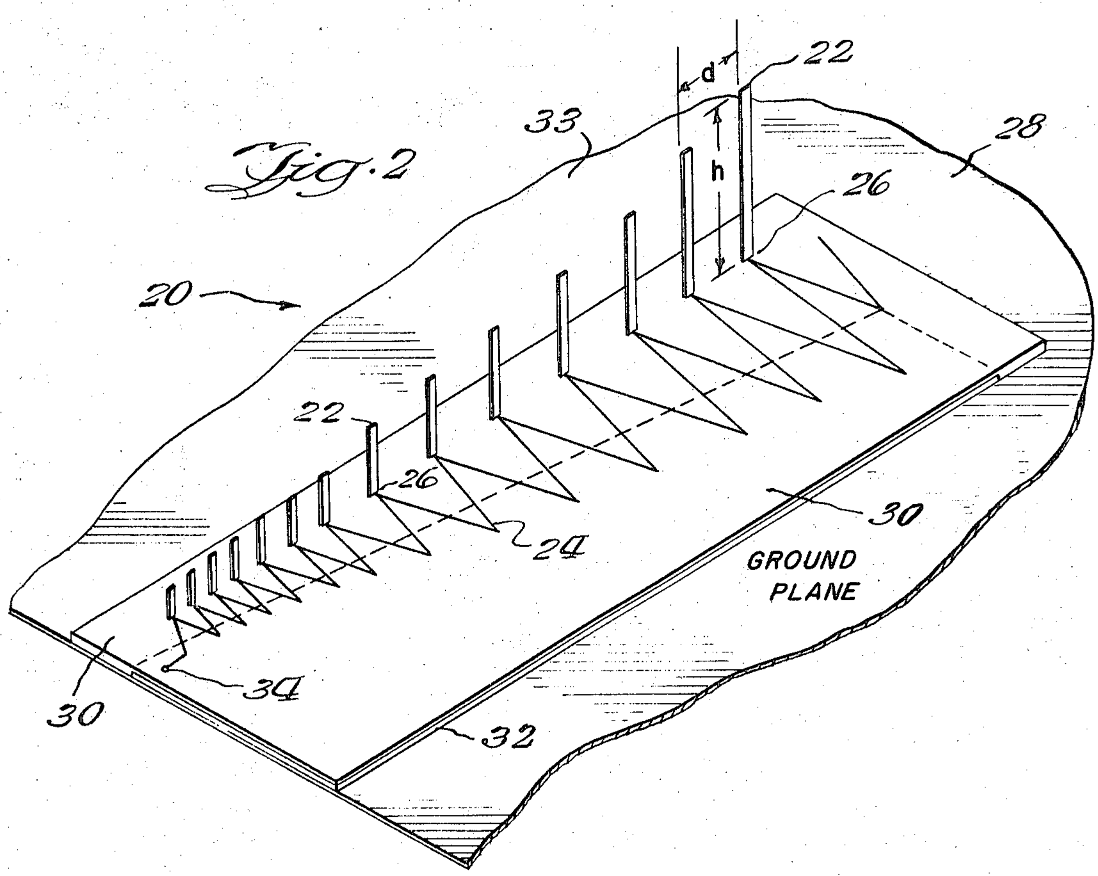


Fig. 2

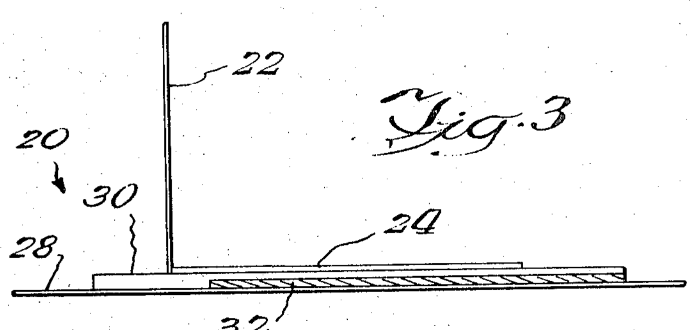


Fig. 3

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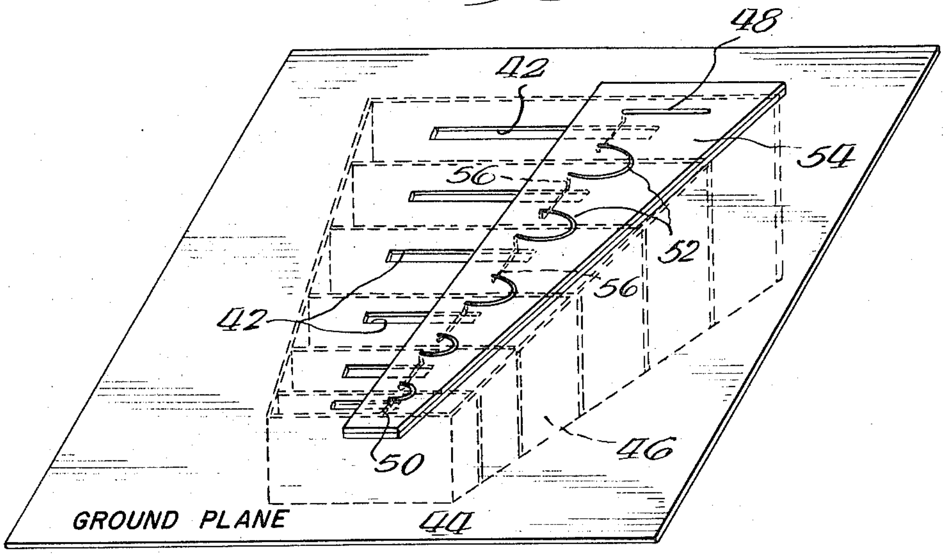
Fig. 4



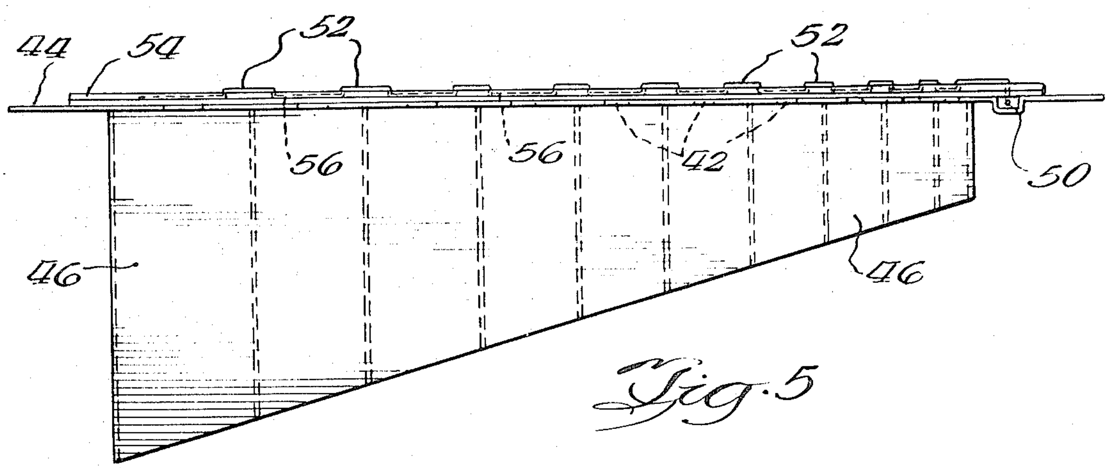


Fig. 5

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Fig. 6

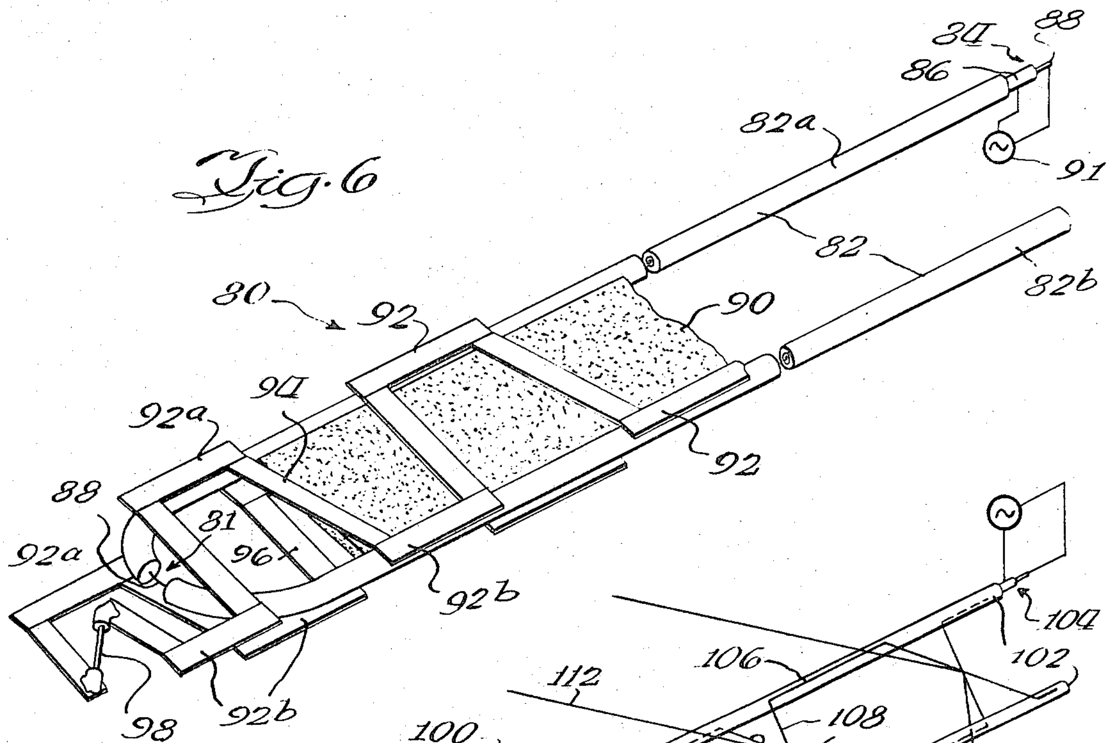


Fig. 7

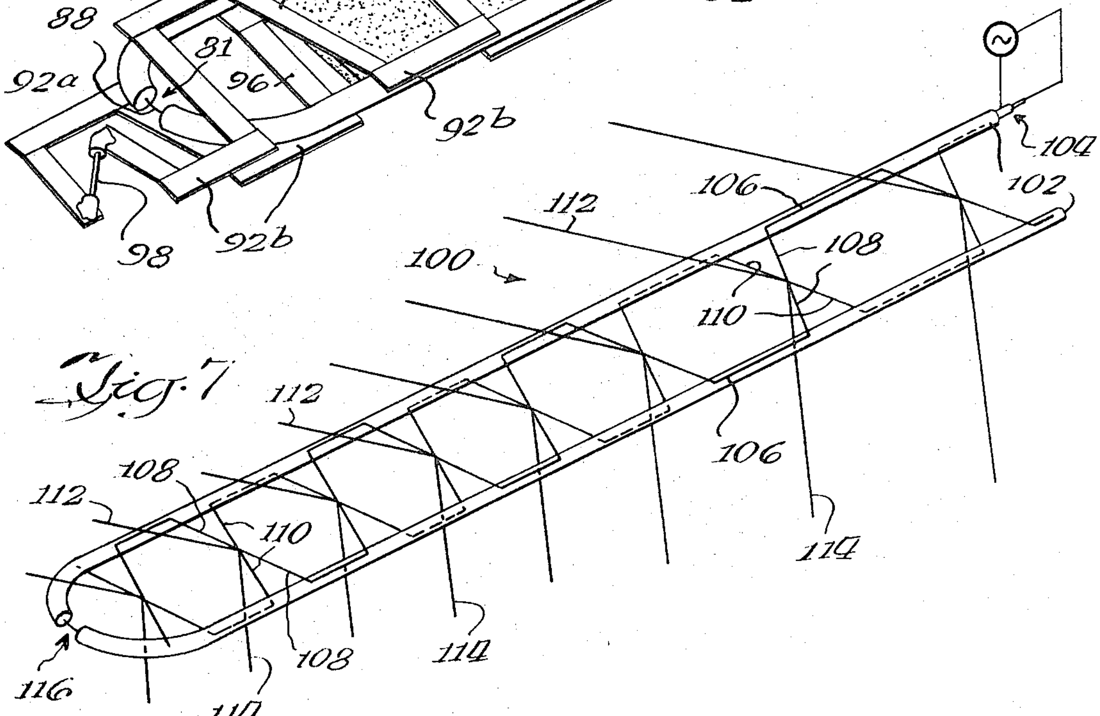
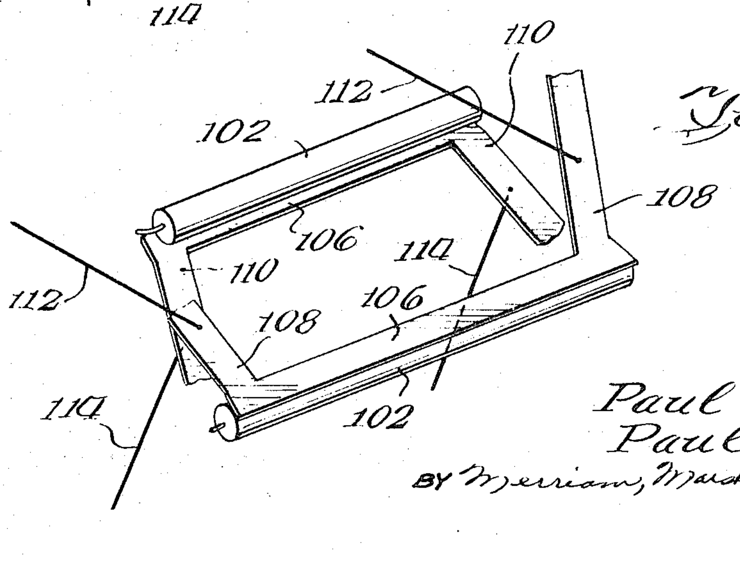


Fig. 8



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MODULATED IMPEDANCE FEEDING SYSTEM FOR LOG-PERIODIC ANTENNAS

BACKGROUND OF THE INVENTION

This invention relates to antennas and more particularly to a broadband feed system for log-periodic antennas.

Log-periodic geometry is widely used in the design of antennas which cover extremely wide frequency bands. Many log-periodic antennas consist of a uniform impedance transmission line which is loaded with radiating elements at log-periodic spacings. The condition for radiation from such a structure is met when the phase progression from element to element in the array is almost equal to or greater than the free space value.

Since loading a transmission line with either shunt monopoles or series slots produces a reduction in phase velocity, these elements are not good radiators even when resonant, if they are placed closer than a half wave length separation along the line. Several different methods are employed for adjusting the phase shift to increase the radiation from closely spaced elements. The first to be used was a transposition of the feed line between dipoles, which effectively adds an additional π radians phase shift between adjacent dipole pairs to move the radiation (active) region on the antenna ahead of the reflection region. This is the technique used in the construction of the log-periodic dipole array. The transposition of the feeder line, however, spoils the symmetry of the structure and, hence, makes it impossible or difficult in practice to employ half of the dipole array over a ground plane to form a log-periodic monopole array. Neither can the transposed feeder be realized in a slot transmission line version for the purpose of feeding a log-periodic array of slots in a ground plane.

An alternate technique for increasing the phase difference between adjacent loads on a log-periodic structure is to increase the length of transmission line which is used to connect adjacent elements. If the LP (log-periodic) structure is viewed as a cascade of symmetrically loaded cells, then it is apparent that for low input VSWR's, most of the energy must travel with negligible reflections to the radiating part of the structure, usually called the active region. When the structure consists of a uniform line with a length of transmission line longer than one-half wavelength between loading elements in this active region, the radiating elements will be phased for more efficient radiation, but the image impedance of the cells ahead of the active region, i.e. between the feed point and the active region, will have a region where it varies quite rapidly in magnitude and where its value even becomes complex. This causes a stop region of increased local reflection such that most of the incident energy down the structure toward the active region is reflected before it reaches the active region. Such a structure then cannot dissipate essentially all of the incident energy and, hence, the input VSWR is increased. Moreover, as the scaling factor between cells is raised, the effect of this reflection region becomes more pronounced and the input VSWR increases instead of decreasing as is normally expected.

SUMMARY OF THE INVENTION

The present invention effectively removes the first stopband on the periodic structure and hence also the first stop-region on the corresponding log-periodic structure. In accordance with the principles of this invention, there is provided an improved feeding system for log-periodic antennas, wherein a log-periodically spaced step modulation is applied to the feeder. This enables an effective match in the image impedance of the unloaded portion of the line and the loaded portions in the regions where local reflections occur. This invention therefore allows the construction of a lump-loaded transmission line which can have the necessary phase progression for good radiation by the loading elements without the occurrence of the stop region when $\beta d=\pi$. As indicated, this invention is concerned with matching of the image impedances of adjacent cells in the $\beta d=\pi$ region. As used herein the term "cell" is defined as the loading element and length of adjacent line. In order to compensate for the effect of the loading elements, the characteristic impedance of the transmission line is allowed to deviate from its customary value over an appropriate portion of the cell. Thus, instead of a uniform line periodically loaded with radiating elements, the resulting periodic structure has a change in impedance of the feed line in the region about each of the loading elements. This can be conveniently analyzed as a separate loaded section of line which is designed so that the image impedance of this section in the $\beta d=\pi$ region is the same as the impedance of the connecting meandering line.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood from the following detailed description thereof taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic diagram illustrating the principles of the invention;

FIG. 2 is a schematic diagram illustrating a log-periodic monopole array fed with a modulated impedance meandering line, as an example of the principles of this invention;

FIG. 3 is a sectional view of the antenna structure of FIG. 2, illustrating the construction thereof;

FIG. 4 is a schematic diagram illustrating a log-periodic cavity-backed slot array fed with a modulated impedance meandering line according to the invention;

FIG. 5 is a sectional view of the antenna structure shown in FIG. 4;

FIG. 6 is a schematic diagram illustrating a log-periodically scaled directional coupler; and

FIGS. 7 and 8 illustrate a coupler fed, log-periodic resonant V array according to another aspect of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A schematic diagram of an image-matched periodic structure 10 for the case of shunt-loading is shown in FIG. 1. The structure 10 represents schematically a feed line having shunt loading elements 12 and 14 periodically connected to the line, with the characteristic impedance of the line being periodically changed. As indicated in FIG. 1, Z_1 is the characteristic impedance of line length d, in the vicinity of shunt admittance Ys; whereas Z_o is the characteristic impedance of line length $d2$. Ordinarily when the line lengths between loads are about one-half wavelength the structure displays a stopband. The matching of the image or characteristic impedance in this band is the condition for no energy reflection, thereby eliminating the stopband up to the first resonance of the elements. The feeder can also be considered to be a line with periodically modulated impedance. Such a modulation of impedance would also produce a stopband. However, addition of the loading elements 12, 14, etc. is just that needed to eliminate the stopband. When log-periodic scaling is applied to this structure, the effects of the first stopband are no longer observed. Thus, more energy is able to reach the resonant elements (which are phased for good radiation) and the input VSWR to the structure is greatly improved.

The foregoing illustration, which has been described for lumped resonant circuit loading on the transmission line, has been tested in the design and construction of antennas employing resonant radiating elements. One example is shown in FIG. 2 which is a schematic diagram of a log-periodic monopole array 20. Each monopole element 22 is connected to and extends transversely from a meandering feed line 24 at connection points 26, the line 24 being suitably supported in position above the ground plane 28 by insulating means such as an insulating block 30. The excess line length is chosen to provide near optimum conditions for backfire radiation from the resonant monopoles. The characteristic impedance of the meandering feed line 24 is modulated by means of an aluminum plate 32 which is placed between the feed line and the ground plane 33 as shown most clearly in FIG. 3. Thus, in the vicinity of the monopoles, the spacing of the feeder above the ground plane is greater than in the region above the aluminum plate. The characteristic impedance of the line 24 in the vicinity of the monopoles 22 is, therefore, greater than that of the remaining part of the meandering line. The relative length of the portions of line with different characteristic impedances for the monopole array 20 of FIG. 2 was easily altered by pivoting the aluminum plate about the point at the virtual apex of the log-periodic structure. In practice, such variations are unnecessary after the desired impedance characteristics have been obtained, so that the plate 32 can be replaced by suitable means interconnecting the line 24 at the required positions. The array 20 is suitably fed between the feed point 34 and the ground plane 28.

No attempt was made to optimize the design of the monopole antenna except for the adjustment in the relative lengths of the portions of the feeder with different characteristic impedances. Nevertheless, it was possible to reduce the VSWR with respect to a mean impedance of 75 ohms to a value less than 2.1:1, which is a significant improvement over an unmodulated feeder in a log-periodic monopole array.

A modulated impedance feeder has also been applied to the design of a log-periodic array of cavity-backed slots. The loading produced by a slot in the ground plane under a single wire transmission line can be represented approximately by a series element. In this sense, the problem of the slot array becomes the dual of the monopole case. To eliminate the stopband which would be produced by a periodic array of the slots, it is necessary to decrease the characteristic impedance of the feed line in the vicinity of each slot, as opposed to increasing the impedance near the monopoles. The relative impedance between slot and feeder is easily adjusted by offsetting the position of the feeder from the center line of the slot. The radiation from one side of the slots can be eliminated by backing each slot with a metallic cavity.

A log-periodic cavity-backed slot array 40 is shown in FIG. 4 and 5. The array of slots 42 with log-periodic variation in size and spacing is cut in the ground plane 44. Each slot is backed by an individual metallic cavity 46. The cavity dimensions also vary in a log-periodic fashion. The array is fed from a single wire line 48 over the top of the slots at the feed point 50. The characteristic impedance of the feed line in the vicinity of the slots is determined by the thickness of the insulation on the feeder conductor. The connecting line sections 52 of meandering line are of sufficient length to provide backfire phasing from the active region. The sections 52 of the feeder are spaced a greater distance from the ground plane 44 by means of an insulating sheet 54 than the straight line sections 56 extending across the slots, but not connected thereto. A scale factor τ=0.925 and spacing parameter σ=0.15 was used for an experimental model constructed as illustrated in FIGS. 4 and 5. The resulting VSWR indicated that the stopband has been effectively removed by means of the modulation of the feeder impedance. For purposes of illustration, referring to FIG. 2, the spacing parameter σ, which is the spacing in wavelength in the active region, is defined as $\sigma=d/4h$, where h is the height of the longest monopole and d is the spacing between any two adjacent monopoles.

It is to be understood that while distributed elements have been illustrated herein for modulating the impedance of the feeder line in accordance with the invention, it is within the skill of the art to substitute lumped elements associated with the radiating elements.

Another quite different problem associated with a first stopband occurs in the operation of multimode log-periodic dipole arrays. In this case, the first active region is associated with dipoles which are one-half wavelength in tip-to-tip dimension and higher order active regions are associated with dipoles which are odd integer multiples of one-half wavelength. It has been shown previously that the directivity and gain associated with the higher order active regions are considerably greater than those of the half-wave region. However, the excitation of the higher order active regions by a generator located at the smallest dipole is possible only if there are no half-wave dipoles on the antenna between the generator and the higher order active region. Thus, the bandwidth of operation of the three half wavelengths mode is theoretically limited to three to one and the practical realization of this mode of operation has been achieved over bands of approximately 2.5:1.

A structure 80 containing two transmission lines with a scaled coupling region between the lines has been developed and is illustrated in FIG. 6. This structure can be used to bypass the half-wave-length active region (or a low-frequency stop-region which might occur on a log-periodic structure for some other reason). In this case, the excitation is applied to the gap 81 in a two-wire balanced line 82 (with oppositely disposed line sections 82*a* and 82*b*), by a coaxial feed cable 84 having a center conductor 88 and a concentric outer conductor 86. Suitable insulating means 90 are provided between the line sections 82*a* and 82*b* to maintain proper separation. Although for purposes of illustration the lines 82*a* and 82*b* are indicated as being substantially parallel, if desired, these lines may be tapered somewhat inwardly towards each other from the signal source and towards the gap 81 end. If desired, instead of the coaxial cable 84, a balanced transmission line could be connected to the gap 81.

The lines 82*a* and 82*b* comprise hollow tubular conductors, with the coaxial cable 84 inserted through and extending within the conductor line 82*a*. Outer coaxial cable conductor 86 is connected to the conductor line 82*a*, whereas the center coaxial cable conductor 88 passes through conductor line 82*a* and is connected to conductor line 82*b*. Thus, line 82*a* is an electrical extension of the outer coaxial conductor, while line 82*b* is an electrical continuation of the coaxial cable center conductor.

A second (coupled) two-wire line 92 having conductor line sections 92*a*, 92*b* includes transpositions 94 and 96 between the conductors which occurs at log-periodically spaced distances along the line. Line sections 92*a* are connected to and extend along conductor 82*a*, and similarly line sections 92*b* extend along conductor 82*b*. The energy which is launched from a signal source 91 on the first two-wire line 82 is coupled in the reverse direction to the coupled line 92 having transposed conductors 94 and 96. The location of the coupling region is determined by the spacing between adjacent transposes in terms of wavelength. The coupled energy is then carried back to a suitable termination 98 at the gap end of the coupled line. Since the coupling region scales with frequency, the impedance seen at the excitation gap on the first line changes very little with frequency when the second line is properly terminated.

The log-periodic scaled directional coupler is especially useful as a feeder for antenna arrays. As an example of this aspect of the invention, a log-periodic resonant V array 100 is shown in FIG. 7. The first two-wire line 102, coaxial cable 104, and the two-wire coupled line 106 are constructed in a manner similar to that shown in FIG. 6, although it is to be understood that other embodiments, such as wire lines can be substituted for the flat ribbon two-wire coupled line 92 of FIG. 6. At log-periodically spaced distances along the line 106, transpositions 108 and 110 extend between the two lines 106 similar to transpositions 94 and 96 of FIG. 6. A series of V dipole elements 112 are connected to the transpositions 108, and a corresponding series of V dipole elements 114 are connected to the transpositions 110. The dipole elements extend angularly away from and on opposite sides of a plane containing the coupled line 106, as is shown more clearly in FIG. 8. Thus, the paired V dipole elements form an array of V dipoles connected across the log-periodically scaled coupled line 106, and the feed line is excited across the gap 116.

The antenna 100 is designed so that the coupling between the feed line 102 and the coupled line 106 occurs in the region immediately behind a group of dipoles which are near resonance. Excitation of the dipoles is then achieved by the wave which is traveling back along the coupled line 106 toward the feed point of the antenna at gap 116. The dipole-to-dipole phase progression in the vicinity of the resonant elements is thus approximately the same as that for a free-space wave traveling toward the feed point.

In a constructed array for operation in the three-half-wavelength mode, the angle between the halves of the V dipoles was adjusted to minimize the level of the sidelobes which are present in the E-plane pattern of the three-half-wavelengths dipole. Since the energy is now carried past the half-wave dipole region on the feeder line, the bandwidth for the three-half-wave mode on the resonant V array is theoretically unlimited. The actual operating bandwidth, of course, is limited by the ratio of the lengths of the largest to the smallest dipoles on the antenna. The high gain and excellent front-to-back ratio which is generally achieved in the higher mode operation of resonant V arrays has also been obtained using the log-periodic coupler feed as illustrated herein.

It is to be understood that the scaling from cell to cell of the structure does not have to be exactly log-periodic to obtain a working structure. As with the conventional log-periodic dipole array, variations in scaling and cell size are possible with corresponding somewhat inferior results, but for the widest band performance, the log-periodic scaling is the most desirable. Reference may be had to U.S. Pat. No. 3,210,767 issued Oct. 5, 1956, to D. E. Isbell, herein incorporated in its entirety, wherein such now well known log-periodic scaling is described in detail.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

What is claimed is:

1. In log-periodic antennas having a series of substantially log-periodically scaled antenna elements including a feeder periodically coupled to said antenna elements to form loaded and unloaded portions along said feeder, the improvement comprising:

modulated impedance matching means for modulating the characteristic impedance of said feeder in the region near said antenna elements relative to the characteristic impedance of said feeder away from said antenna elements,

said modulated impedance matching means thereby matching the image impedances of said loaded feeder portions at said antenna elements with the adjacent unloaded feeder portions.

2. In log-periodic antennas having a series of substantially log-periodically scaled antenna elements including a feeder periodically coupled to said antenna elements to form loaded and unloaded portions along said feeder, the improvement comprising:

impedance-matching means coupled to said feeder for matching the image impedances of said loaded feeder portions to said antenna elements with the adjacent unloaded feeder portions;

said antenna elements comprising a series of monopole elements projecting transversely above a ground plane and periodically coupled to said feeder, said impedance-matching means including means for increasing the characteristic impedance of said feeder in the region near said monopoles above the characteristic impedance of said feeder away from said monopoles.

3. The improvement of claim 2, wherein said impedance-matching means comprises means for supporting said feeder in the region near said monopoles a greater distance above said ground plane than the distance between said ground plane and the remaining portion of the feeder away from the monopoles.

4. In log-periodic antennas having a series of substantially log-periodically scaled antenna elements including a feeder periodically coupled to said antenna elements to form loaded and unloaded portions along said feeder, the improvement comprising:

impedance-matching means coupled to said feeder for matching the image impedances of said loaded feeder portions at said antenna elements with the adjacent unloaded feeder portions;

said antenna elements comprising a ground plane and a series of slots therein, and wherein said feeder is spacially separated from said slots on one side of said ground plane, said impedance-matching means modulating the characteristic impedance of said feeder in the vicinity of said slots.

5. The improvement of claim 4, wherein said impedance-matching means includes means for supporting said feeder above said slots closer to the ground plane than the distance between the ground plane and the remaining portion of the feeder away from the slots.

6. The improvement of claim 5, including a series of log-periodically scaled cavity sections associated with each of said slots to form a log-periodic cavity backed slot array.

7. In log-periodic antennas having a series of substantially log-periodically scaled antenna elements extending from a feed point, the improvement comprising a log-periodically scaled directional coupler feed line, said feed line including:

a first transmission line having oppositely disposed conducting line elements extending from said feed point at one end of said series of antenna elements towards the opposite end;

a second transmission line having oppositely disposed conducting line elements respectively coupled to said first line along the length thereof;

a series of transposition elements interconnecting the conducting line elements of said second transmission line at substantially log-periodically spaced distances along said line; and

means for connecting said antenna elements to said respective transposition elements along said line,

whereby an electromagnetic wave traveling from said feed point on said first transmission line towards said opposite end, is coupled to said second transmission line and travels thereon back towards said feed point to excite said antenna elements.

8. The improvement of claim 7, wherein said first transmission line comprises a coaxial cable having a center conductor and a concentric outer conductor, said coaxial cable extending from said feed point toward said opposite end of said series of antenna elements, the outer conductor of said coaxial cable defining one of said first transmission line elements, and the center conductor of said coaxial cable electrically extending from said feed point toward the opposite end of said series of antenna elements to define the other of said first transmission line elements.

9. The improvement of claim 7, wherein said antenna elements comprise a series of V dipole elements each connected to a respective one of said transposition elements to form an array of V dipoles connected across said second transmission line.

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