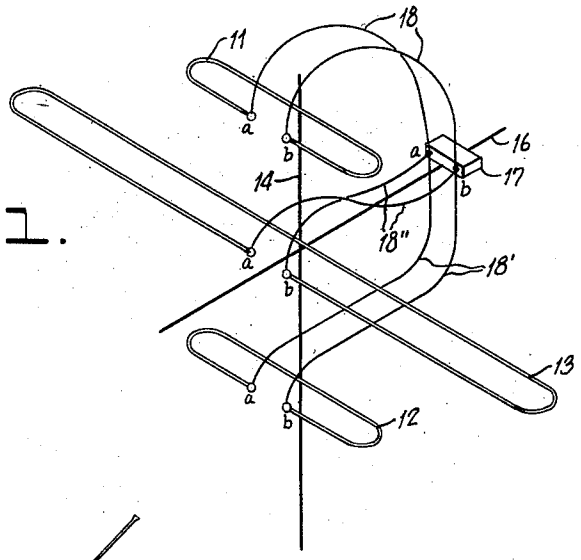
Jan. 28, 1958 YUEN TZE LO 2,821,711

WIDE BAND ANTENNA

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Fig. 1.



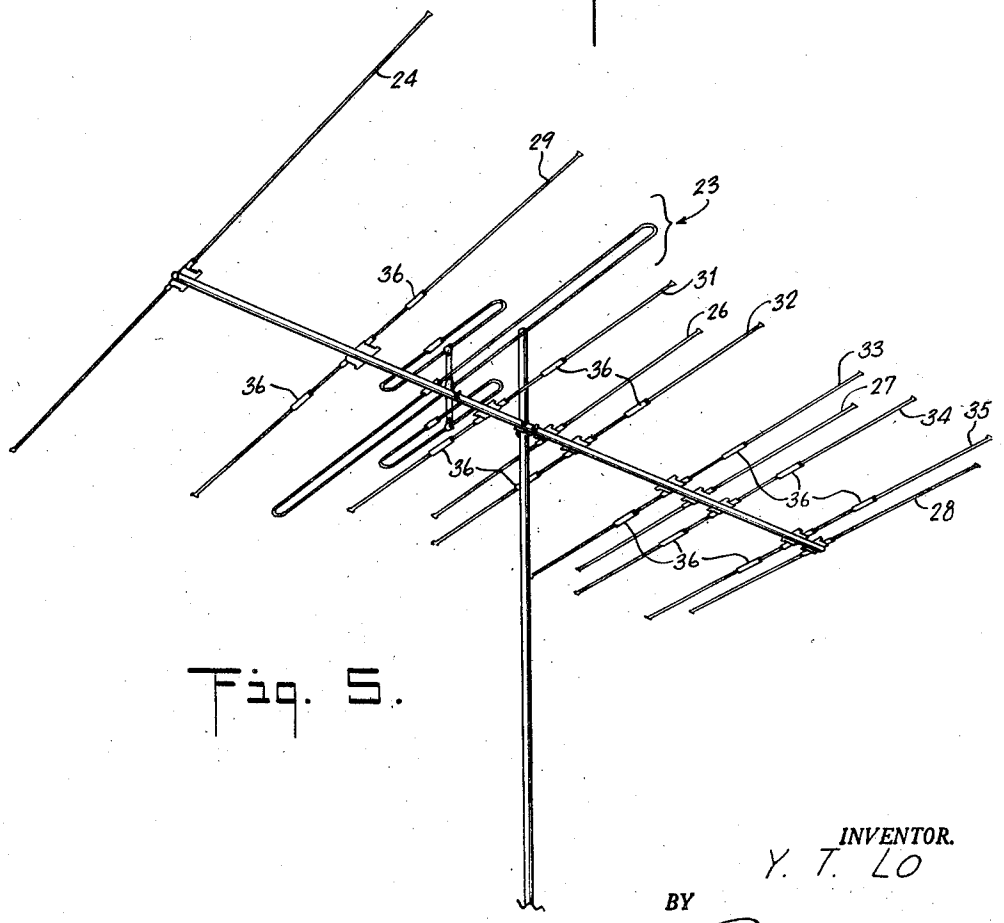


Fig. 5.

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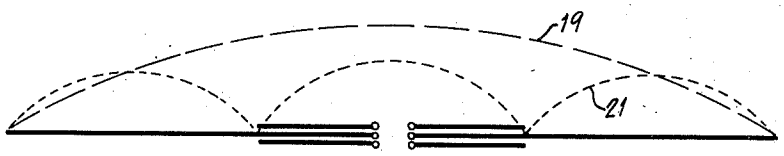


Fig. 2.

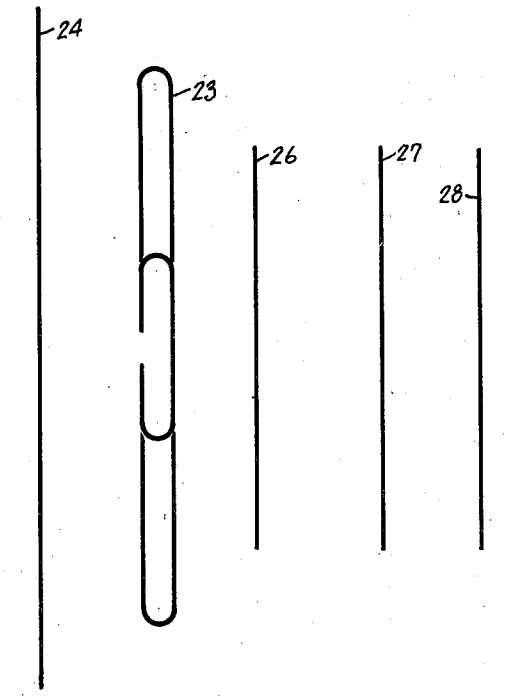


Fig. 3.

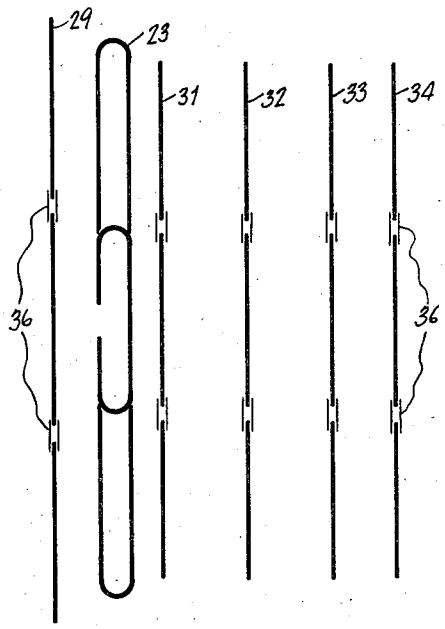


Fig. 4.

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WIDE BAND ANTENNA

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Application September 17, 1954, Serial No. 456,799

11 Claims. (Cl. 343—819)

The present invention relates to improvements in wide band antennas, especially for commercial television reception.

Present commercial television broadcasting in the very-high-frequency (V. H. F.) portion of the broadcast spectrum is allocated to a low band including channels 2 to 6, extending between 54 and 88 megacycles per second, and a high band for channels 7 to 13 extending between 174 and 216 megacycles per second. This overall frequency ratio of 4 to 1 has made extremely difficult the problem of providing a single antenna structure which will receive all these channels with practically uniform high gain, flat frequency response, narrow polar patterns yielding high directivity, and high front-to-back discrimination to eliminate interference from transmitters in other than desired directions.

One antenna which has generally satisfied these requirements is the Channel Master "Champion" antenna described and claimed in my copending application, Serial No. 418,553, filed March 25, 1954, and entitled "Wide Band Antenna," now Patent No. 2,691,730, granted October 12, 1954. This prior antenna uses a "tri-pole" array having three dipoles in a single vertical plane, with the top and bottom dipoles resonant near the center of the high band and the center dipole resonant near the center of the low band, the three dipoles being intercoupled by a transmission line harness with the center dipole having reversed connections relative to the other two dipoles. Such a tri-pole assembly has been found to yield highly efficient all-channel coverage.

The present invention constitutes an improvement on the "Champion" antenna, utilizing the same tri-pole assembly with a simpler and economical system of parasitic elements for providing improved gain and other characteristics adapted especially for fringe and "super-fringe" reception areas in addition to secondary reception areas.

The present invention also provides a novel combination of parasitic director and reflector elements with an active element to provide wide-band coverage previously considered unattainable with such parasitic elements.

The present invention in addition provides an improved form of parasitic element cooperating with active elements operating on higher modes.

The present invention further provides a novel combination of a pair of separate parasitic element systems with a single active antenna element to provide extended band coverage.

It also provides an improved interleaved arrangement of low and high band parasitic director elements for wide band operation.

Other objects and advantages of the present invention will become more apparent from consideration of the following description of preferred forms of the present invention taken in conjunction with the appended drawings in which:

Fig. 1 is a perspective view of a tri-pole array;

Fig. 2 is a schematic diagram useful in explaining the principles and operation of the tri-pole array;

Fig. 3 is a schematic plan view of one form of the present invention useful in covering the entire low band;

Fig. 4 is a similar view of another form of the present invention useful particularly in covering the entire high band;

Fig. 5 is a schematic perspective view of a general form of the present invention useful for both low and high bands.

Referring to Fig. 1, the tri-pole array is formed by a vertical arrangement of three dipoles 11, 12, 13 shown in this instance as folded dipoles, although other dipole forms may be used. In the present illustrative form, each of the folded dipoles 11, 12, 13 is formed by an elongated loop of conductive material such as aluminum, interrupted in one long side to form two terminal ends, each loop lying in a horizontal plane, and the three dipoles being stacked vertically one above the other as by being mounted on a vertical post 14 which in turn is supported from a horizontal antenna cross arm 16 on which other elements are mounted as described below. The dipoles 11, 12 are high-band dipoles, being identically resonant at a frequency near the center of the high V. H. F. television band, while dipole 13 is a low-band dipole resonant at a frequency near the center of the low V. H. F. television band, and is approximately three times as long as each of the high-band dipoles 11 and 12. A terminal block 17 is provided, secured to cross arm 16 or any other convenient location, and having terminals *a* and *b*, taken for convenience as respectively on the left and right as viewed in Fig. 1. Each of the dipoles 11, 12, 13 also has respective left and right terminals *a*, *b*, as seen in Fig. 1. A transmission line harness 18, 18', 18'' connects the dipole terminals *a*, *b*, to the terminals *a*, *b* of terminal block 17. As seen in the figure, terminals *a*, *b* of the high-band dipoles 11 and 12 are connected by harness branches 18 and 18' to respective terminals *a*, *b* of the block 17. However, terminals *a* and *b* of low-band dipole 13 are connected by harness branch 18'' in reverse fashion, being connected to terminals *b* and *a*, respectively, of terminal block 17.

The resultant effect of the three dipoles 11, 12, 13 and harness 18, 18', 18'' is illustrated by Fig. 2, where the dashed line 19 shows the equivalent current distribution of the tri-pole assembly for low-band operation, and the dotted line 21 shows such distribution for high-band operation. It will be seen that the assembly operates like a single half-wave dipole on the low band, and like three colinear half-wave dipoles operating in phase on the high band. This latter effect compensates for the normal lower reception level on the high band caused by smaller effective receiving aperture and higher frequency, and hence provides desirable enhanced gain for the high band. This high-band operation is hence equivalent to that of three in-line and in-phase dipoles, and this is utilized by the special parasitic element system described below.

The overall effect of the array just described is to provide substantially uniform gain over both the low and high V. H. F. bands of television broadcasting.

According to the present invention a wide-band antenna, such as the tri-pole array just described, is combined with parasitic director and reflector elements to provide an antenna arrangement of relatively compact construction permitting economical manufacture, with an in-line design giving easy assembly and clean appearance, and providing high gain and sharp directivity.

In prior antenna design, for higher gain and directivity as well as front-to-back discrimination reflectors have been used. For wide-band operation, such reflectors have needed to be substantially non-resonant, and a screen or grid-type reflector has been used. Such reflectors are of course uneconomical to manufacture because of the large amounts of material required, and are bulky in use and in shipment because of their necessarily large size

for non-resonance. Resonant-type reflectors which reduce these disadvantages have been avoided because they have necessarily narrowed down the band width over which the antenna could be used. Parasitic directors and reflectors have also been used with resonant antennas to enhance the gain and directivity thereof. These directors and reflectors have necessarily been sharply tuned to the frequency of the resonant antenna and were hence critical in their dimensions. The resultant effect has also been to narrow the useful frequency range and to make the complete array much more frequency sensitive.

The present invention departs from this prior practice and uses a wide band active antenna element, such as the tri-pole assembly, in combination with differently tuned director and reflector parasitic elements. This is shown in one form in Fig. 3, which represents schematically in plan view a tri-pole assembly **23** with a parasitic reflector element **24** and parasitic director elements **26, 27, 28** shown as three in number for illustrative purposes only. For use on the low band, the reflector **24** is tuned substantially at the lower edge of the frequency band, while the directors **26, 27, 28** are tuned substantially at the higher edge of the band. For channels 2 to 6, ranging between 54 and 88 megacycles per second (or 219 and 134 inches in wave-length), by way of example, reflector **24** may be approximately 106 inches long and directors **26, 27, 28** may be approximately 62 inches long, for a representative size of aluminum tubing such as ⅜ inch, and with the following spacings from the tri-pole assembly

	Inches
Element **24**	41
Element **26**	18
Element **27**	47
Element **28**	72

The length of each element will vary somewhat if its diameter or spacing from the tri-pole assembly is changed. In general, due to cross-section and end effects, and for proper phasing, the physical length of parasitic element is somewhat less than the theoretical resonant length, by up to about 20% at the highest frequencies. In addition, for some modifications in spacing, directors **26, 27, 28** may not be exactly equal in length, but may vary slightly. Although three directors and one reflector are shown here, forming an array generally similar to a 5-element "Yagi" array, fewer or more directors may be used according to the requirements of gain and directivity, a greater number of directors providing greater gain and sharper directivity, but at the expense of uniformity over the band. In general, for more directors, those farther from the active element **23** will be slightly shorter than those nearer to element **23.**

This arrangement of Fig. 3, by the use of a wide-band active element and the differently tuned reflector and director elements, provides an antenna arrangement useful over the entire low band, as contrasted with conventional Yagi arrays which have been useful only for one or (with reduced effectiveness) for two adjacent channels.

As indicated above, for the high band of channels 7 to 13, between 174 and 216 megacycles per second (about 68 to 55 inches in wavelength), the tri-pole assembly acts like three co-linear in-phase dipoles, having the characteristic shown at **21** in Fig. 2. For this band, a desirable parasitic element array is as shown in Fig. 4, where the tri-pole assembly **23** has a reflector element **29** on one side and four director elements **31, 32, 33, 34** on the other side. Here again, the number of directors is merely illustrative.

According to a further feature of the present invention, the reflector **29** and directors **31—34** are not formed of a single conductive rod as in Fig. 3, but are in three co-linear sections which are insulated from each other, thereby providing an individual reflector and director array for each of the three equivalent half-wave dipoles of the tri-pole assembly on high-band operation. Here again the reflector is tuned approximately to the lower edge of the frequency band and the directors to the upper band edge. Thus, reflector **29** may have each of its three sections about 31 inches long and the directors **31** to **34** may have each of the three sections about 22 inches long. These dimensions also may vary somewhat according to diameter of the parasitic elements and their spacing from the tri-pole array. The three segments of each element need not be exactly equal, but may differ slightly. Preferably symmetry is maintained by having the end segments equal. The spacings utilized are generally similar to those used for conventional Yagi antennas.

While the configurations of Figs. 3 and 4 are highly useful for their respective bands, in practice it is desirable to use a single arrangement for both bands. According to another feature of the present invention it has been discovered that two sets of parasitic elements such as shown in Figs. 3 and 4 may be simultaneously utilized with a single tri-pole assembly to provide dual band coverage without any loss in gain or other desirable characteristics. Such an arrangement is shown in perspective in Fig. 5. High-band reflector **29** is here between low-band reflector **24** and tri-pole assembly **23.** First segmented high-band director **31** is between the tri-pole assembly **23** and the first low-band director **26.** Second segmented high-band director **32** is just beyond the first low-band director **26.** Third and fourth segmented high-band directors **33** and **34** straddle the second low-band director **27.** The fifth segmented high-band director **35** is between the third low-band director **28** and the remaining elements. Thus the two parasitic element systems of Figs. 3 and 4 have been interwoven, with the addition of a further high-band director **35.** Each high-band element is segmented, being formed by separate rods joined and supported by insulating spacers such as **36.**

In such interweaving of the parasitic elements, their lengths may differ slightly from those of the simpler systems of Figs. 3 and 4, due to coupling and interaction between high- and low-band elements. In general, the high-band elements have very little effect upon the low-band elements, because the high-band elements depart to such an extent from any resonant condition encountered in low-band operation. Hence the spacings of the low-band parasitic elements will be substantially the same as in Fig. 3. However, the reverse is not true, since the low-band elements may have resonances at higher modes during high-band operation. Also, in general, the length of each element is more critical than its spacing. For this reason, the low-band element spacings used in the interleaved configuration of Fig. 5 are those found to be optimum for that band separately, but the high-band element spacings are in general determined by the low-band element positions. To overcome the possibly undesirable effects of the low-band elements during high-band operation, a resonant high-band element is associated relatively closely to each low-band element, and spaced therefrom so that the resultant effect of the low-band element and associated high-band element is substantially equivalent to that of a single high-band element at a position between the two. Since the high-band element spacings are smaller than the low-band element spacings due to the high frequencies of operation, five high-band elements are used with three low-band elements.

The high-band and low-band reflectors are positioned substantially as they are in Figs. 3 and 4. The first high-band director **31** (closest to the tri-pole) is also positioned substantially as in Fig. 4. The low-band directors **26, 27, 28** are positioned substantially as in Fig. 3. The remaining high-band directors **32, 33, 34, 35** are located so as to provide proper high-band operation despite the effects of the low-band directors **26, 27, 28.** The high-band director segments operate on their fundamental mode, being substantially ½ wave length at the upper

edge of the high-band and hence less than ½ wave length at other channels. The low-band directors, however, in high-band operation will operate in a higher mode. As a result, the high-band element excitation is stronger than that of the low-band element, permitting the use of high-band elements to "over-ride" the effects of low-band elements. For this purpose, a high-band element is closely associated with each low-band element, the spacing between the low-band element and its associated high-band element (or in the case of low-band director **27**, both associated high-band directors **33** and **34**) being a small fraction of the spacing between low-band directors, such as 20% or less.

As in Figs. 3 and 4, the reflector dimensions are determined by the lower edge frequency of each band, and the director dimensions are determined by the higher edge frequency of each band, which prevents erratic variation in gain and directivity over each band.

In addition, since the high band is roughly three times the low band in frequency, a given change in element length will have three times the effect on the high-band characteristics that it will have on the low-band characteristics. This affords a simple way of making a final design adjustment. Each set of low-band and high-band parasitic elements is first designed for optimum performance in its respective band, taken separately. After the elements are interleaved to form the Fig. 5 configuration, a "trimming" adjustment is made by slight changes in low-band element dimensions to afford a desired performance on the high band, while keeping such changes small enough to have no substantial effect on low-band performance. In this way any undesirable effects of the low-band elements upon the high-band elements is compensated for; at the same time, the low-band performance is not affected.

A highly effective resultant antenna configuration for the present commercial television V. H. F. bands was attained with the following dimensions:

Element	Length (in.)	Spacing from Tri-Pole (in.)
24	106	41
29	31½—31½—31½	15
11	28	0
12	28	0
13	89	0
31	22¼—21½—22¼	7
26	62	18
32	22¼—21½—22¼	23
33	22¼—21½—22¼	42
27	62	47
34	22¼—21½—22¼	52
35	22¼—21½—22¼	68
28	62	72

The insulators **36** may be formed of suitable insulating material, such as polystyrene, "Teflon" or the like, about 5 inches long leaving about 3 inches between the adjacent ends of the high-band parasitic element segments.

It will be noted that for the high-band directors **31** to **35**, the center segment is shorter than the end segments of each element. This is believed caused by the effect of the cross-arm on which the center segment is mounted, and to a slight extent to the capacitive effect of the insulators **36**. These effects are strongest for the highest frequencies, and may usually be disregarded for the high-band reflector **29**.

It will be understood that for other bands or frequency ranges correspondingly modified dimensions would be used.

While Fig. 5 shows essentially three sets of directors (**31—26—32**; **33—27—34**; and **35—28**), where the ultimate in gain, directivity and front-to-back discrimination is not required, either the last director set **35—28** or both the second and last sets **33—27—34** and **35—28** may be omitted. Conversely, in especially difficult "super-fringe" areas it may be desirable to add further sets of directors. In such case, preferably each set except possibly the end set is made as a "sandwich" of two high-band directors with a low-band director in between. The director spacings for each band are determined as indicated above [those found to be optimum for that band in the absence of the elements for the other band].

Where especially high gains are required, two or more antennas of the present invention may be "stacked," that is, used in multiple, one above another. In such case, the vertical spacing is preferably 80 to 100 inches, using coupling transmission line sections about ¼ wave length long at the center of the low band (which is about ¾ wave length long at the center of the high band) and of a characteristic impedance of approximately 380 ohms between each pair of antennas.

The present invention hence provides a highly useful wide-band antenna arrangement, effective over both the low and high television bands, having two-bay gains (referred to a simple dipole) of the order of 6 to 8 decibels for the low band and 10 to 13 decibels for the high band, with a flat frequency response over each channel width, with desirably sharp directivity, and with front-to-back voltage ratios up to 10:1. The antenna is economical and easy to manufacture and assemble, and is readily adapted for folded or knocked-down packaging.

It will readily be understood that the foregoing description is illustrative only and is not to be taken as restricting the scope of the present invention, which is defined by the appended claims.

What is claimed is:

1. An antenna arrangement for both low and high bands comprising a wide-band active element adapted to receive both said bands, a low-band parasitic reflector element parallel to and horizontally spaced from said active element, a high-band parasitic reflector element parallel to and interposed between said low-band reflector element and said active element, a plurality of sets of parasitic director elements parallel to and horizontally spaced from said active element on the side opposite to said reflector elements, each of said director element sets comprising a low-band director element and at least one high-band director element, one high-band director element of each set being between said active element and the low-band director element of such set, all but one of said director element sets consisting of a low-band director element between two high-band elements, said low-band reflector element being tuned approximately to a half wavelength at the lowest frequency in said low band, said low-band director elements being tuned approximately to a half wavelength at the highest frequency in said low band, each of said high-band parasitic director and reflector elements being formed as a set of three co-linear conductive segments and a rigid insulator supporting each of the end segments from the center segment, each segment of said high-band reflector element being tuned approximately to a half wavelength at the lowest frequency in said high band, and each segment of said high-band director elements being tuned approximately to a half wavelength at the highest frequency in said high band but with the center segment of each of said high-band elements being shorter than the end segments thereof.

2. An antenna arrangement for both low and high frequency bands comprising a wide-band active element adapted to receive both said bands, a low-band parasitic reflector element parallel to and horizontally spaced from said active element, a high-band parasitic reflector element parallel to and interposed between said low-band reflector element and said active element, a plurality of sets of parasitic director elements parallel to and horizontally spaced from said active element on the side opposite to said reflector elements, each of said director element sets comprising a low-band director element and at least one high-band director element, one high-band director element of each set being between said active element and the low-band director element of such set, all but one of said director element sets consisting of a

low-band director element between two high-band elements, each of said high-band parasitic reflector and director elements being formed as a set of three co-linear conductive segments and a rigid insulator supporting each of the end segments from the center segment.

3. An antenna arrangement comprising an active element adapted to receive over a band of frequencies, a first set of parasitic reflector and director elements adjacent to said active element, and a second set of parasitic reflector and director elements interleaved with said first set and each tuned to a different frequency from that of said first set, each director element of said second set being formed of three co-linear segments each insulated from the other and each director element of said first set except one being between a respective pair of elements of said second set.

4. An antenna arrangement comprising an active element adapted to receive over a band of frequencies, a first set of parasitic director elements adjacent to and on one side of said active element, and a second set of parasitic director elements interleaved with said first set and each tuned to a different frequency from that of said first set, each director element of said second set being formed of three co-linear segments and a rigid insulating member supporting each outer segment from its respective center segment, and each director element of said first set except the one farthest from said active element being between a respective pair of elements of said second set.

5. An antenna arrangement for both low and high bands comprising a wide-band active element adapted to receive both said bands, a low-band parasitic reflector element parallel to and horizontally spaced from said active element, a high-band parasitic reflector element parallel to and interposed between said low-band reflector element and said active element, a plurality of sets of parasitic director elements parallel to and horizontally spaced from said active element on the side opposite to said reflector elements, each of said director element sets comprising a low-band director element and at least one high-band director element, one high-band director element of each set being between said active element and the low-band director element of such set, all but the outermost one of said director element sets consisting of a low-band director element between two high-band director elements, said low-band reflector element being tuned approximately to a half wavelength at the lowest frequency in said low band, said low-band director elements being tuned approximately to a half wavelength at the highest frequency in said low band, and said high-band director elements being tuned approximately to a half wavelength at the highest frequency in said high band.

6. An antenna arrangement for both low and high bands comprising a wide-band active element adapted to receive both said bands, a plurality of sets of parasitic director elements parallel to and horizontally spaced from said active element on one side thereof, each of said sets of director elements comprising a low-band director element and at least one high-band director element, one high-band director element of each set being between said active element and the low-band director element of such set, all but the outermost one of said director element sets consisting of a low-band director element between two high-band director elements, each such low-band director element with its two associated high-band director elements constituting one of said sets, said low-band director elements being tuned approximately to a half wavelength at the highest frequency in said low band, and said high-band director elements being tuned approximately to a half wavelength at the highest frequency in said high band.

7. An antenna arrangement for dual low and high frequency bands comprising an active element adapted to receive both said bands, a plurality of sets of parasitic director elements adjacent to and on one side of said active element, each of said director element sets comprising a low-band director element and at least one high-band director element, each except the outermost one of said director element sets consisting of a low-band director element between a respective pair of high-band director elements, said low-band director elements being tuned approximately to a half wavelength at the highest frequency in said low-band, and each of said high-band director elements being tuned approximately to a half wavelength at the highest frequency in said high band.

8. An antenna arrangement for both low and high bands comprising a wide-band active element adapted to receive both said bands, a low-band parasitic reflector element parallel to and horizontally spaced from said active element, a high-band parasitic reflector element parallel to and interposed between said low-band reflector element and said active element, a plurality of sets of parasitic director elements parallel to and horizontally spaced from said active element on the side opposite to said reflector elements, each of said director element sets comprising a low-band director element and at least one high-band director element, one high-band director element of each set being between said active element and the low-band director element of such set, and all but one of said director element sets consisting of a low-band director element between a respective pair of high-band elements.

9. An antenna arrangement for both low and high bands comprising a wide-band active element adapted to receive both said bands, a plurality of sets of parasitic director elements parallel to and adjacent said active element on one side thereof, each of said director element sets comprising a low-band director element and at least one high-band director element, one high-band director element of each set being between said active element and the low-band director element of such set, and all but one of said director sets consisting of a low-band director element between a respective pair of high-band director elements.

10. An antenna arrangement for both low and high bands comprising a wide-band active element adapted to receive both said bands, a low-band parasitic reflector element adjacent said active element, a high-band parasitic reflector element interposed between said low-band reflector element and said active element, and a plurality of sets of parasitic director elements adjacent said active element on the side opposite to said reflector elements, each of said director element sets comprising a low-band director element and at least one high-band director element with each low-band director element except the outermost one being between a respective pair of high-band director elements.

11. An antenna arrangement comprising an active element adapted to receive over a band of frequencies, a first set of parasitic director elements adjacent to said active element, and a second set of parasitic director elements interleaved with said first set and tuned to a different frequency from that of said first set, each element of said first set except the one farthest from said active element being between a respective pair of elements of said second set.

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