

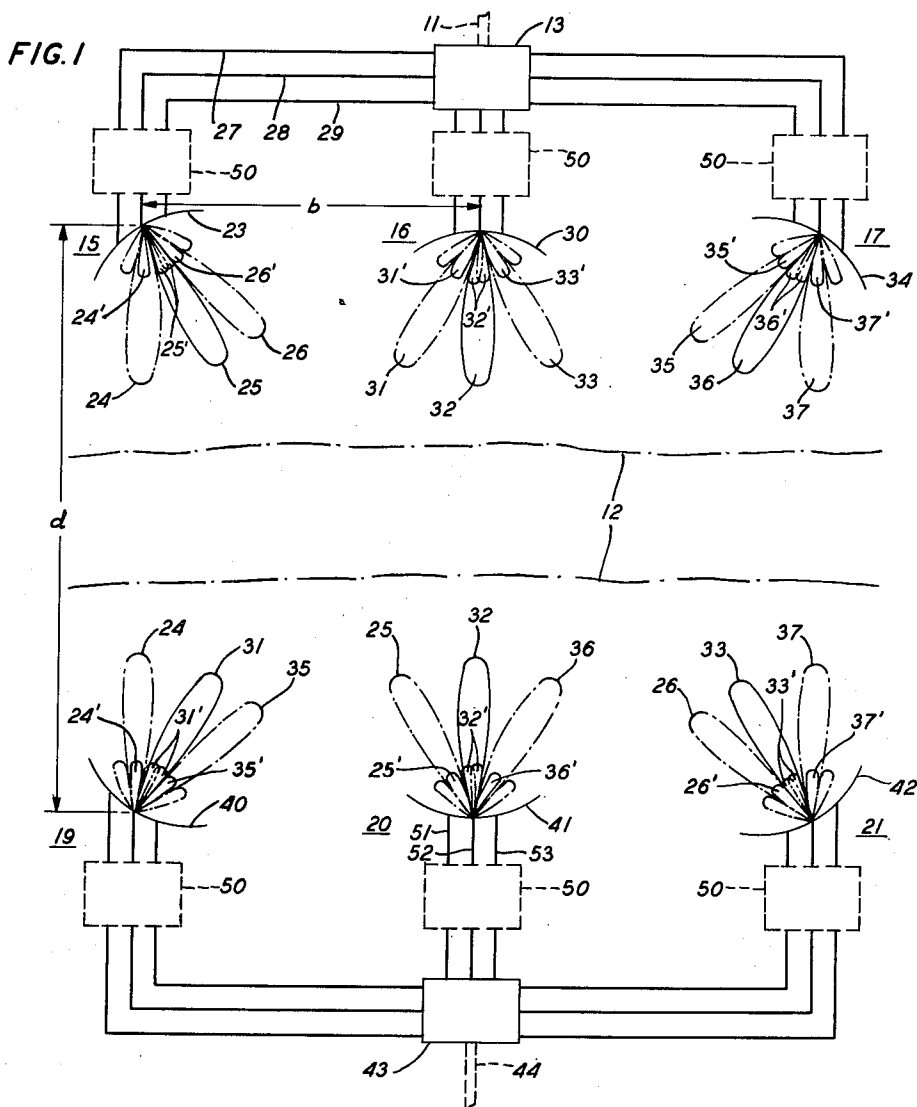
Feb. 6, 1962

TINGYE LI
CROSS-TALK CANCELLATION APPARATUS FOR
BROADBAND MICROWAVE RADIO LINKS

3,020,543

Filed May 24, 1960

3 Sheets-Sheet 1



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FIG. 4A

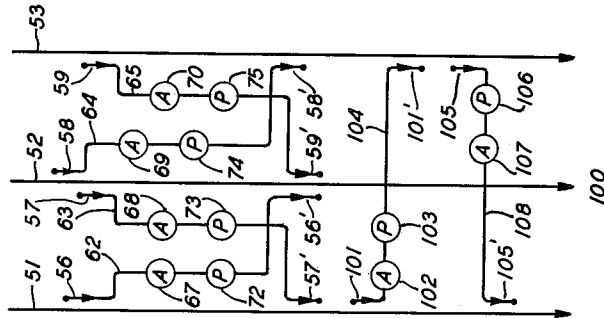


FIG. 3

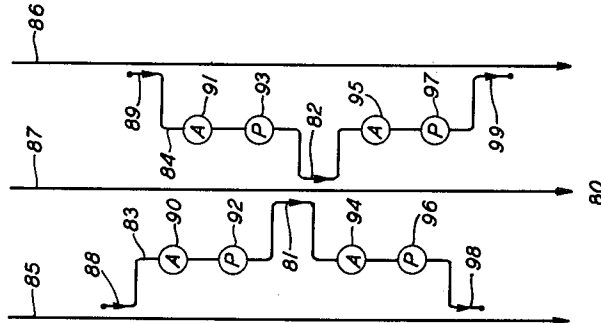
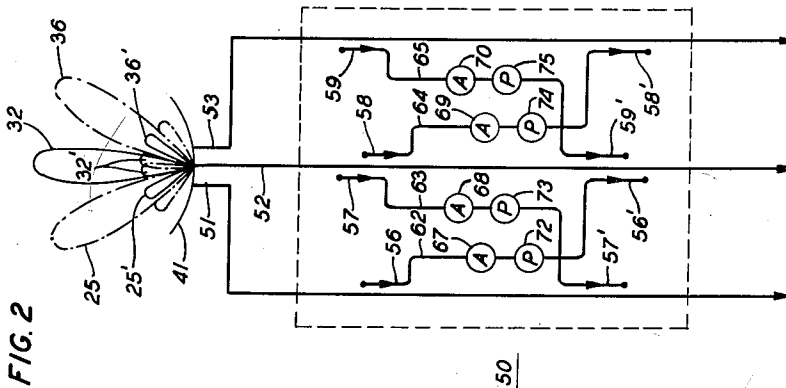


FIG. 2



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FIG. 4C

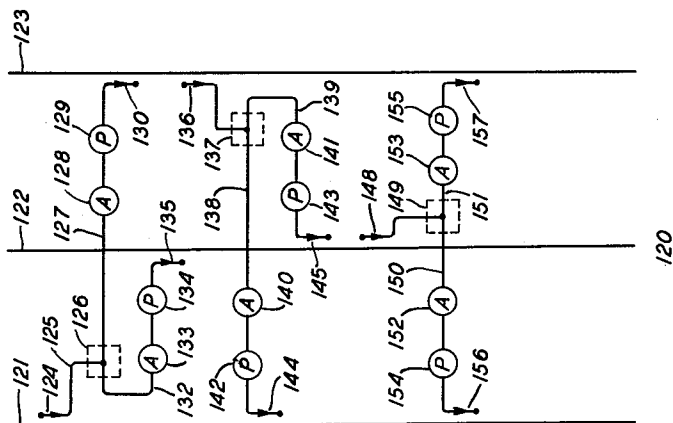
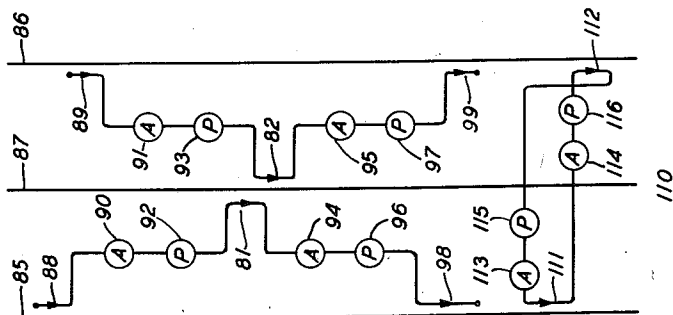


FIG. 4B



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3,020,543

CROSS-TALK CANCELLATION APPARATUS FOR BROADBAND MICROWAVE RADIO LINKS

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Filed May 24, 1960, Ser. No. 31,353

6 Claims. (Cl. 343-100)

This invention relates to microwave communications and, more particularly, to a broadband radio link employing a plurality of narrow band microwave relay channels.

In a copending application of H. T. Friis, Serial No. 861,976, filed December 24, 1959, there is disclosed a broadband radio link utilizing antenna directivity for either bridging a terrain obstacle in a cross-country guided wave system, for example, or providing a segment of a cross-country system comprising a plurality of such links connected in cascade. In the described radio link, the broadband signal applied thereto, such as from a terminated end of a cross-country wave guide, is divided into a plurality of distinct narrow band channels occupying the same common carrier frequency band. A plurality of these narrow band channels of signal information are then transmitted from each of a plurality of first antenna locations to a plurality of second antenna locations.

Each of the first antenna locations in such a radio link comprises a plurality of feeds severally associated with a plurality of major lobes of a single antenna (or of a plurality of adjacent antennas) for radiating the signal information along adjacent paths displaced by acute angles from each other to the plurality of second locations spaced from each other and from the first locations. Each of the second locations similarly comprises a plurality of feeds severally associated with a plurality of major receiving lobes of a single antenna (or of a plurality of adjacent antennas) severally directed toward a different one of the radiating signal paths.

The antennas in such a system are preferably of the multilobe, multifeed type utilizing a common spherical or parabolic reflector; however, separate antennas, compactly grouped at each location may also be utilized. Unless special precautions are taken in such a microwave system, each major radiating or receiving lobe oriented along a given signal path at each location normally gives rise to at least one minor side lobe which may be in substantial alignment with an adjacent signal path, thereby causing cross-talk or interference in the multichannel system.

As pointed out in the aforementioned Friis application, the minimizing of interference or cross-talk in such a wide band radio link is sought by the use of directional selectivity. Maximum discrimination between two adjacent radiating or receiving major lobes occurs if the angle θ between these lobes is such that the major lobe of one falls upon the null between the major lobe and the first minor side lobe of the other. However, if more than two antennas (or two major lobes) are employed at a single location, which, for reasons of economy, simplicity and space to mention but a few, is usually desired, no given angle θ will make it possible for every major lobe to fall upon a null in the pattern of every other antenna (or major lobe) at that location.

Further, even in a microwave system utilizing only two adjacent antennas (or major lobes), the critical angle θ referred to above might often necessitate more land for the radiating and/or receiving antenna locations than could be economically purchased or developed. This situation could arise because of the fact that the angle θ is determined by the ratio of the spacing between the

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respective radiating and receiving antenna locations to the distance separating the radiating antennas from the receiving antennas. Moreover, while narrow beam antennas with low minor side lobes are preferred, prior known techniques for minimizing side lobes, such as by tapering of an antenna array, for example, have not proven feasible and/or adequate in a multilobe arrangement of the type hereinabove described to the extent that the minor side lobes give rise to no appreciable cross-talk or interference.

Accordingly, it is an object of this invention to reduce cross-talk due to undesired minor side lobe reception or radiation in a broadband microwave radio link utilizing antenna directivity.

It is a more specific object of this invention to substantially reduce the cross-talk between a plurality of major lobes of a single antenna (or of a plurality of adjacent antennas), displaced by acute angles from each other, these lobes constituting separate, adjacent paths for either radiating or receiving distinct narrow band channels of signal information.

In accordance with this invention, at each antenna location in a radio link of the aforementioned type, a signal energy of the proper phase and magnitude is sampled and fed back from each intended path to every other path which would normally either have a portion of its energy radiated along, or receive energy from the intended path through the aforementioned type of minor side lobe interference. The necessary cross-coupled feedback circuitry preventing undesired side lobe interference is associated with the feeds of the respective major lobes (or paths) and may comprise any one of a number of different types of well known directional couplers with adjustable phase and attenuation circuitry either incorporated therein or associated therewith.

A complete understanding of this invention and of these and other features thereof may be gained from a consideration of the following detailed description taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a diagrammatic representation of a multilobe, multifeed broadband radio link showing both the desired major lobes and the undesired minor lobes which give rise to a form of cross-talk with which the instant invention is concerned with suppressing.

FIG. 2 is a schematic representation of a single multilobe, multifeed antenna of the type depicted in FIG. 1 in conjunction with cross-coupled feedback circuitry embodying the principles of this invention; and

FIGS. 3, 4A, 4B and 4C are schematic illustrations of alternative cross-talk cancellation circuits embodying the principles of this invention.

FIG. 1 depicts diagrammatically a broadband radio link of the type disclosed in the aforementioned copending Friis application and, in particular, depicts the orientation of and the relationship between the major and minor lobes at each of the transmitting and receiving antenna locations as well as therebetween. Such a radio link is shown in FIG. 1 for the purpose of facilitating a more complete understanding of the significance and importance of the cross-talk cancellation circuit embodying principles of this invention to be described in detail hereinafter. Considering the radio link briefly, in one particular application, a broadband signal propagating in a cross-country wave guide 11 approaches a terrain obstacle, such as represented between the dotted lines 12. The guide 11 is terminated in a suitable terminal building 13 in which are located repeater amplifiers, power supplies and the like. Included also is conventional means for dividing the broadband signal in guide 11 into a plurality of narrow band channels and for translating the frequency of each into the same common carrier band. In the particular embodiment illustrated,

nine such channels are employed and each contemplated, for example, as having a 1000 megacycle bandwidth and each being translated so that it occupies the common carrier band of 10.7 to 11.7 kilomegacycles.

Disposed in a horizontal array along one side of the terrain obstacle 12 is a plurality of radiating antenna locations 15, 16 and 17 displaced from each other by a distance b and the array spaced by a distance d from a plurality of receiving antenna locations 19, 20 and 21. The distance b is generally considerably less than the distance d and, hence, requirements on the antenna directivity may be exceedingly stringent if cross-talk is to be kept at a minimum. Provided at each of the radiating antenna locations 15, 16 and 17, is means for radiating n separate radio beams, each occupying for example, a 1000 megacycle bandwidth and a relatively narrow beam width. As illustrated, a single multilobe, multi-feed antenna, such as 23 having n separate feeds and n major lobes, such as lobes 24, 25 and 26, is employed at each location. Such an antenna may be of the multifeed parabolic type disclosed in A. C. Beck Patents 2,409,183, issued October 15, 1956, and 2,495,219, issued January 24, 1950. Separate wave guide paths 27, 28 and 29 connect each feed of antenna 23 to the channel branching and frequency translating equipment in terminal building 13. A similar antenna 30 radiating lobes 31, 32 and 33 is located at 16 and an antenna 34 radiating lobes 35, 36 and 37 is located at 17.

Similarly, at each of the spaced receiving antenna locations 19, 20 and 21, is a multilobe, multifeed antenna 40, 41 and 42, respectively, so positioned that one major lobe of each is directed to receive signal information from a different major lobe of each of the radiating antennas. In FIG. 1 mutual alignment of the respective radiating and receiving lobes is indicated by identifying such lobes with the same reference numeral. Thus lobe 24 of antenna 23 is in substantial alignment with lobe 24 of antenna 40, lobe 25 is in alignment with lobe 25 of antenna 41 and lobe 26 is in alignment with lobe 26 of antenna 42, et cetera. Similarly, lobes 31, 32 and 33 of antenna 30 and lobes 35, 36 and 37 of antenna 34 are in substantial alignment with the correspondingly identified lobes at antennas 40, 41 and 42, respectively. The several narrow band (1000 megacycle) channels of signal information received by the separate major lobes at antennas 40, 41 and 42 are carried by separate feed wave guides to terminal building 43 where they are translated in frequency as required and recombined for further transmission as a broadband signal in guide 44 which forms the continuation of guide 11 on the opposite side of the terrain obstacle. Of course a plurality of these radio links could be connected in cascade to cover longer distances. As thus far described, the broadband microwave radio link comprises the system disclosed in the aforementioned copending Friis application. As will be described in detail hereinafter in accordance with principles of this invention, a cross-talk cancellation circuit 50 is shown in block form connected to the feeds adjacent each of the radiating and receiving antennas.

In accordance with the characteristics of any narrow beam, non-isotropic antenna, there are normally two or more minor side lobes associated with each major lobe. As previously mentioned, these minor side lobes generally coincide, at least in part, with one or more adjacent major lobes of a multilobe antenna (or with one or more major lobes of a plurality of adjacent single lobe antennas). For example, at radiating antenna 23, minor side lobes 24' and 26' associated with major lobe 25 coincide with major lobes 24 and 26, respectively. This overlapping of major and minor radiating lobes, representative of different narrow band channels of signal information, often gives rise to serious cross-talk or interference as a result of reception along an undesired path at the receiving antenna locations. For example, the energy radiated by minor side lobes 24' and 26' of antenna

23 could be received by major lobes 24 and 26 of receiving antennas 40 and 42, respectively, in addition to the intended signal information respectively directed thereto by the major radiating lobes 24 and 26 of antenna 23. Similarly, at receiving antenna 41, for example, it is seen that the minor side lobes 25' and 36' associated with major lobe 32 are in substantial alignment with major receiving lobes 25 and 36 of antennas 23 and 34, respectively, rather than with the intended radiating lobe 32 of antenna 30. Accordingly, it becomes apparent that the energy received by the minor side lobes 25' and 36' of antenna 41 may be representative of an appreciable and undesired amount of cross-talk when added to the intended signal energy received by the major lobe 32. The intended mutual alignment between the various other major radiating and receiving lobes is indicated in FIG. 1 by using the same reference numeral to identify each major lobe of a radiating antenna which is directed toward a given major lobe of one of the receiving antennas. Similarly, the major and coincident minor lobes which give rise to undesirable cross-talk are identified by the same reference numerals, the numeral identifying the coincident minor lobes being primed.

It will now be described in detail, in accordance with the principles of this invention, how the undesired cross-talk normally due to minor side lobe reception or radiation in a multilobe, multifeed antenna system of the type depicted in FIG. 1 is substantially eliminated.

FIG. 2 schematically depicts a single multilobe, multifeed antenna 41 in conjunction with a cross-talk cancellation circuit 50, shown only in block form in FIG. 1, embodying the principles of this invention. Antenna 41 in FIG. 2 corresponds to and is identified by the same reference numeral as the receiving antenna at location 20 in FIG. 1 in order to facilitate a discussion of the operating principles of this invention hereinafter. Antenna 41, as seen in FIG. 2, utilizes three feeds, 51, 52 and 53, preferably comprising wave guides, extending away from the spherical or parabolic concave reflector of antenna 41, as shown, to the cross-talk cancellation circuit 50 enclosed within the dotted-lined box. Continuing out of the circuit 50, feed lines 51, 52 and 53 may extend to and terminate in a terminal building of the type described in FIG. 1 or, in certain other applications, they may connect directly to suitable receiving or transmitting apparatus, not here shown.

In accordance with a feature of this invention, the cross-talk cancellation circuit 50 of FIG. 2 would of course be utilized at each of receiving antenna locations 19, 20 and 21 in a system of the type depicted in FIG. 1. For example, as utilized at location 20, this circuit is designed to sample and feed back signal energy of the proper magnitude and phase received in each of feeds 51, 52 and 53 from major lobes 25, 32 and 36, respectively, which are severally oriented toward different receiving paths, to each of the adjacent feeds which receives energy from the intended path through minor side lobe reception. Such a circuit would similarly be utilized at each of the radiating antenna locations in a microwave system of the type depicted in FIG. 1 as will be described in greater detail hereinafter.

To accomplish the aforementioned type of cross-talk cancellation, circuit 50 of FIG. 2 comprises four pairs of directional couplers 56-56', 57-57', 58-58' and 59-59' which interconnect feeds 51-52, 52-51, 52-53 and 53-52, through cross-coupled wave guide sections 62, 63, 64 and 65, respectively. The directional couplers may be of any of the well known types such as those utilizing a plurality of quarter wavelength spaced apertures, a long-slot, a capacitance loop or the Bethe-hole arrangement for coupling energy into or out of the feed associated therewith, for example. Typical two and three hole directional couplers are described in "Principles and Applications of Waveguide Transmission" by R. P. Southworth, D. Van Nostrand Co., Inc., pages 346-352 (1950).

Refinements of certain of these couplers for high frequency, broad bandwidth applications are disclosed in patents of S. E. Miller, 2,701,340, and A. G. Fox, 2,701,342, both issued February 1, 1955. Alternatively, the directional couplers may utilize the resonance phenomenon of ferrites as disclosed in the patents of S. E. Miller, 2,849,683; M. T. Weiss, 2,849,685, and E. H. Turner, 2,849,686, all issued August 26, 1958, and A. G. Fox, 2,896,174, issued July 21, 1959. Inasmuch as the directional couplers may take any one of a number of well known and commercial forms, they have been shown in only schematic form in circuit 50 in the interest of simplicity and convenience and with such representation believed more clearly to indicate their significance in accordance with the principles of this invention. The dot on the extreme end of each of the directional couplers in circuit 50 designates a substantially reflectionless termination. The arrow in connection with each directional coupler indicates the direction in which signal energy is either transferred to or transferred from the particular feed associated with each directional coupler.

Adjustable attenuators 67, 68, 69 and 70 and phase shifters 72, 73, 74 and 75 are associated with the cross-coupled wave guide sections 62, 63, 64 and 65, respectively. The attenuators may comprise any one of a number of well known and commercial forms, such as those utilizing an adjustable dielectric slab coated with a suitable absorbing material and movable either laterally or rotatively within the guide feeds. An adjustable flap attenuator, for example, may similarly be employed. Of course it is to be understood that the directional couplers may incorporate adjustable coupling means and, thus, a separate attenuator in each guide section as shown would not be necessary. S. E. Miller Patent 2,820,202, issued January 14, 1958, discloses a directional coupler incorporating means for controlling the degree of power transfer from a main guide to an auxiliary guide.

The phase shifters 72-75 similarly may comprise any one of a number of well known and commercial forms, such as the "line stretcher," an adjustable low loss dielectric slab within the wave guide, tuning screws, slug tuners or the like. The phase shifter in each cross-coupled wave guide section is important in that it may be difficult to couple energy from each of the feeds to those adjacent thereto in corresponding regions which are exactly the same distance from the horn-end of each of the feeds and with each cross-coupled wave guide section being of exactly the same length. Thus, the phase shifters are utilized to compensate for such differences in a practical, physical construction of the circuit 50.

The operating characteristics of the cross-talk cancellation circuit 50 of FIG. 2 may be understood best from a consideration of both FIGS. 1 and 2. As seen from FIG. 1, minor side lobes 25' and 36' of receiving antenna 41 are in substantial alignment with major radiating lobes 25 and 36 of antennas 23 and 34, respectively. Since each of the corresponding major radiating and receiving lobes 25, 32 and 36 constitute transmission paths for distinct narrow band channels of signal information, the minor side lobes 25' and 36' of receiving antenna 41 would normally result in the reception of cross-talk energy in the center feed associated with the center major lobe 32.

In order to substantially cancel this type of cross-talk due to minor side lobe reception, energy received from the major lobe 25 of receiving antenna 41, with which minor lobe 25' is coincident, is fed back to the center feed 52, as seen in FIG. 2, in magnitude corresponding to the undesired energy received by the minor lobe 25' through directional couplers 56-56', attenuator 67 and phase shifter 72, all associated with the cross-coupled wave guide section 62. The phase relationship of the signal being fed back is adjusted such that it will be substantially 180 degrees out of phase with the signal initially received in feed 52 by minor side lobe 25' so as to cancel the otherwise occurring cross-talk therein. Likewise, the unde-

sired signal energy which would normally exist in the center feed 52 by reason of the energy received in minor side lobe 36' is substantially cancelled by feeding back an appropriate amount of the signal energy in the feed 53, associated with the major lobe 36 of antenna 41, to the center feed 52 through the directional couplers 59-59', attenuator 70 and the phase shifter 75, all associated with the cross-coupled guide section 65.

In a similar manner undesired cross-talk signal energy normally received in feeds 51 and 53 associated with major lobes 25 and 36, respectively, resulting from a minor side lobe 32' of each being in substantial alignment with major lobe 32, is cancelled by feeding back signal energy of the proper magnitude and phase from the feed associated with major lobe 32 to each of feeds 51 and 53 through the directional couplers 57-57', 58-58', attenuators 68, 69 and phase shifters 73, 74 associated with cross-coupled wave guide sections 63 and 64, respectively. It is of course clear that circuit 50, as disclosed in FIG. 2, would be similarly used in conjunction with the feeds adjacent receiving antennas 19 and 21 in a system of the type depicted in FIG. 1 as indicated by circuit 50 being shown in block form adjacent these antennas.

As previously mentioned, the cross-talk cancellation circuit 50 is equally applicable at each of the radiating antenna locations 15, 16 and 17 of the system in FIG. 1 as evidenced by circuit 50 being shown in block form therein. The basic difference in application of circuit 50 at the radiating rather than receiving antenna locations resides in the fact that signal energy of the proper magnitude and phase is fed back through circuit 50 from each input antenna feed associated with an intended major radiating lobe to every other feed associated with a major lobe that would normally have a minor lobe coincident with the intended major lobe. In this case, the signal energy fed back would substantially suppress the existence of an interfering minor radiating side lobe initially. In other words, circuit 50 would feed back signal energy to the respective feeds at each location such that a null would occur in the composite field pattern at every region where an interfering minor lobe maximum would otherwise exist. It is thus seen that the cross-talk cancellation circuit 50 when utilized at the radiating antenna locations substantially suppresses or eliminates the existence of the minor side lobes, whereas at the receiving antenna locations, minor side lobes do exist but the cross-talk arising from their signal reception is substantially cancelled. If the direction of signal transmission in a radio link of the type depicted in FIG. 1 were reversed, the functions of circuit 50 at the original radiating and receiving antenna locations would likewise reverse, thus satisfying the reciprocity theorem applicable to antennas.

FIG. 3 is a schematic representation of a cross-talk cancellation circuit 80 embodying the principles of the instant invention and which differs from circuit 50 in FIG. 2 by a reduction in the number of directional couplers required. In contrast to terminating each of the directional couplers as indicated by the dots in FIG. 2, directional couplers 81 and 82 in FIG. 3 are preferably of the 15 db type with neither of their ends terminated. In operation, the signal energy coupled to the wave guide sections 83 and 84 from feeds 85 and 86 associated with couplers 88 and 89, respectively, is substantially transferred to the center feed 87 upon passing through attenuators 90, 91 and phase shifters 92, 93 associated, respectively, with guide sections 83 and 84. Signal energy in the center feed 87 is coupled to each of feeds 85 and 86 through the couplers 81 and 82, respectively, and then propagates through the attenuators 94, 95 and phase shifters 96, 97 to the directional couplers 98, 99 associated, respectively, with guide sections 83 and 84. As seen in FIG. 3, the extreme ends of the directional couplers 98 and 99 are designed to have substantially reflectionless terminations as indicated by the dotted ends.

The minor disadvantage of circuit 80 as compared to

circuit 50 of FIG. 2 is that the small amount of signal energy which is not coupled to the center feed 87 in passing through directional couplers 81 and 82 continues through guides 83 and 84 and is subsequently fed back into feeds 85 and 86 through couplers 98 and 99, respectively, with perhaps, a slight undesired phase relationship. However, this undesired feedback signal energy is, in general, so small that no significant distortion is encountered.

FIG. 4A depicts a cross-talk cancellation circuit 100, specifically designed to cancel interference normally caused by the undesirable radiation from or reception by a second as well as the first minor side lobe in a given multilobe, multifeed antenna system. Specifically, in a three-lobe antenna pattern, the first and second minor lobes of one outer major lobe might, in certain applications, coincide with the center and other outer major lobes, respectively. To eliminate the cross-talk in such an arrangement, it is necessary to feed back signal energy of the proper magnitude and phase from the feed associated with the intended outer major lobe to the feeds associated with both the center and other outer major lobes.

To effect such feedback in one illustrative embodiment, circuit 100 of FIG. 4A distinguishes over circuit 50 of FIG. 2 by the presence of two additional feedback circuits cross-connecting the outer feeds 51 and 53. The elements of circuit 100 which correspond to those of circuit 50 in FIG. 2 are identified by the same reference numerals for convenience. One of the two additional feedback circuits comprises directional couplers 101, 101', attenuator 102, phase shifter 103 and wave guide 104 for feeding back signal energy of the proper magnitude and phase to feed 53 so as to cancel signal energy therein representative of that energy either radiated from or received by a second minor side lobe of a major lobe associated with feed 51. Conversely, signal energy of the proper magnitude and phase is likewise fed back from feed 53 to feed 51 through directional couplers 105, 105', attenuator 107, phase shifter 106 and wave guide 108 so as to cancel any signal energy therein representative of that energy either radiated from or received by a second minor side lobe of a major lobe associated with feed 53.

Numerous modifications of FIG. 4A are of course possible. For example, FIG. 4B illustrates a cross-talk cancellation circuit 110 which comprises a modification of circuit 80 of FIG. 3 wherein the two outer feeds 85 and 86 are cross-connected by the utilization of two directional couplers 111 and 112. These couplers are preferably of the 15 db type as are couplers 81 and 82 described above with reference to FIG. 3. By utilizing such couplers, any signal energy from feed 85, for example, that is not completely transferred to feed 86 in passing through coupler 112 will not, in general, result in any appreciable distortion in feed 85 by a portion of the signal energy originally coupled therefrom being reintroduced with a slight undesired phase relationship. Attenuators 113, 114 and phase shifters 115, 116 are associated with directional couplers 111 and 112 so as to insure that the energy fed back from the two outer feeds 85 and 86 is of the proper magnitude and phase to insure substantially complete elimination of interference or cross-talk. Such undesired responses could result from the presence of the second minor side lobe of one outer major lobe coinciding with the other outer major lobe and vice versa in a multilobe antenna of the type depicted in FIGS. 1 and 2.

FIG. 4C illustrates schematically another cross-talk cancellation circuit 120 designed to eliminate interference caused by both the first and second minor side lobes in a microwave system of the type depicted in FIG. 1. In this circuit, signal energy from each of feeds 121, 122 and 123 is fed back to each of the other two respective feeds in a manner that completely eliminates the possibility of a portion of such energy fed back reappearing at the original feed with an undesired phase relationship as

may possibly result in circuit 110 of FIG. 4B. Moreover, by the use of three simple hybrid junctions, three less directional couplers are required in circuit 120 than in circuit 100 of FIG. 4A.

Considering the feedback paths more specifically, signal energy of the proper magnitude and phase is fed back from feed 121 to feeds 122 and 123, for example, through directional coupler 124, wave guide section 125, hybrid junction 126, shown in block form, and two distinct branch feedback paths. One of these branch paths connecting feed 121 to feed 123 comprises wave guide section 127, attenuator 128, phase shifter 129 and a directional coupler 130. The other branch path connecting feed 121 to feed 122 comprises wave guide section 132, attenuator 133, phase shifter 134 and directional coupler 135. The hybrid junctions shown only in block form may be of either the E-plane (series tee) or H-plane (shunt tee) types, both of which are well known in the art.

Of course a 3 db directional coupler could be utilized in place of each of the hybrid junctions in circuit 120, however, the junctions would be generally preferred inasmuch as they are not as complex and expensive as high quality directional couplers. As previously mentioned with reference to circuit 50 in FIG. 2, the attenuator and phase shifter in each feedback path in circuit 120 may be incorporated in the directional coupler associated therewith.

Signal energy of the proper magnitude and phase from feed 123 is fed back through directional coupler 136 and hybrid junction 137 to feeds 121 and 122 through guide sections 138, 139, attenuators 140, 141, phase shifters 142, 143 and directional couplers 144 and 145, respectively. Similarly, signal energy of the proper magnitude and phase from the center feed 122 is fed back through directional coupler 148 and hybrid junction 149 to the two outer feeds 121 and 123 through guide sections 150, 151, attenuators 152, 153, phase shifters 154, 155 and directional couplers 156, 157, respectively.

It is thus seen that with any of the circuit arrangements disclosed in FIGS. 4A through 4C, utilized in place of circuit 50 in a system of the type depicted in FIG. 1, interference normally arising from the existence of not only the first but also the second minor side lobe associated with each of the two outer major lobes may be substantially eliminated in accordance with the principles of this invention.

It is to be understood that the specific embodiments described herein are merely illustrative of the general principles of the instant invention. Numerous other structural arrangements and modifications may be devised in the light of this disclosure by those skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. A microwave transmission system comprising means for generating a plurality of major lobes from a plurality of feeds associated respectively therewith from at least one antenna location, said lobes being displaced by acute angles from each other and each being representative of distinct narrow band channels of signal information, each of said major lobes giving rise to at least one minor side lobe which substantially coincides with an adjacent major lobe, and means for cancelling the interference arising from the presence of the coincident minor lobes, said means comprising means for feeding back signal energy of the proper magnitude and phase from each feed respectively associated with each intended major lobe to every other feed respectively associated with every other major lobe normally having a minor lobe coincident with said intended major lobe.
2. An antenna system in accordance with claim 1 wherein said last-mentioned means comprises directional couplers with adjustable attenuation and phase circuitry associated therewith.
3. A microwave transmission system comprising means

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for radiating a plurality of narrow band signal channels in directions displaced by acute angles from each other from each of a plurality of first spaced locations to a plurality of second locations spaced from each other and from said first locations, each of said second locations comprising a plurality of feeds and a plurality of major receiving lobes respectively associated therewith and severally directed toward a different one of said narrow band signal channels, each of said major lobes giving rise to at least one minor side lobe at least partially coinciding with a different one of said major lobes, and means for cancelling the signal energy received by each of said minor side lobes, said means comprising means for feeding back signal energy of the proper magnitude and phase received by each of said major lobes having a minor lobe coincident therewith to the major lobe giving rise to said coincident minor lobe.

4. A microwave transmission system in accordance with claim 3 wherein said last-mentioned means comprises directional couplers with adjustable attenuation and phase circuitry associated therewith.

5. A microwave transmission system comprising a plurality of first spaced radiating antenna locations and a plurality of second receiving antenna locations spaced from each other and from said first locations, each of said first and second locations comprising a plurality of

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feeds and a plurality of major lobes respectively associated therewith, each of said major lobes normally giving rise to at least one minor side lobe substantially coinciding with a different one of said major lobes at each of said locations, the major lobes at said first spaced locations being severally aligned with a different one of said major lobes at said second locations, the respective mutually aligned major lobes defining distinct narrow band channels for the transmission of signal information, and means for substantially eliminating the undesired coincident minor side lobes at each of said first locations and substantially cancelling the signal energy received by each of said undesired coincident minor side lobes at each of said second spaced locations, said means comprising means for feeding back signal energy of the proper magnitude and phase from each feed respectively associated with each intended major lobe normally having a minor lobe coincident therewith to the feed respectively associated with the major lobe giving rise to said coincident minor lobe.

6. A microwave transmission system in accordance with claim 5 wherein said last-mentioned means comprises directional couplers with adjustable attenuation and phase circuitry associated therewith.

No references cited.