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MULTI-DIRECTIONAL ANTENNA SYSTEM

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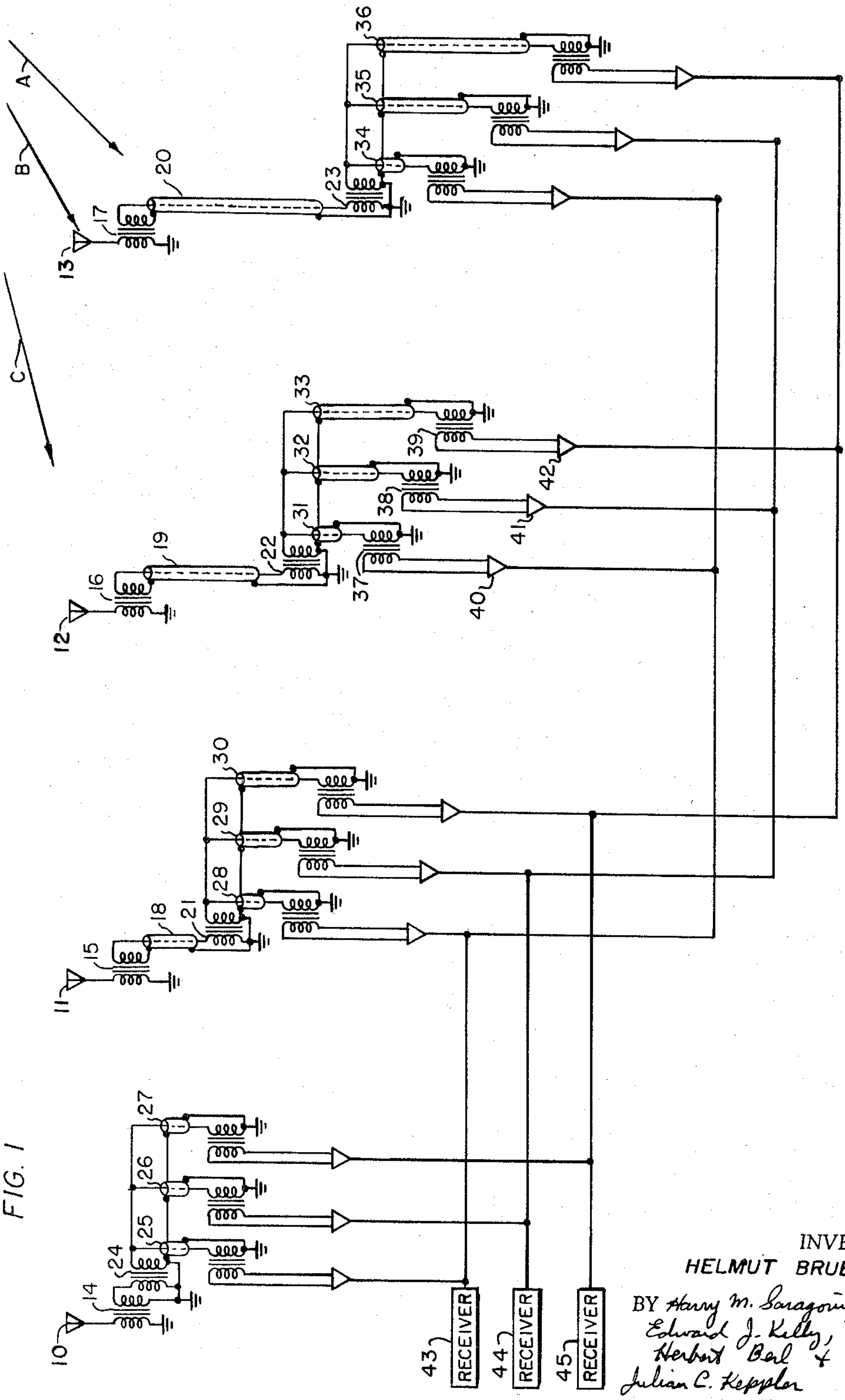

FIG. 1

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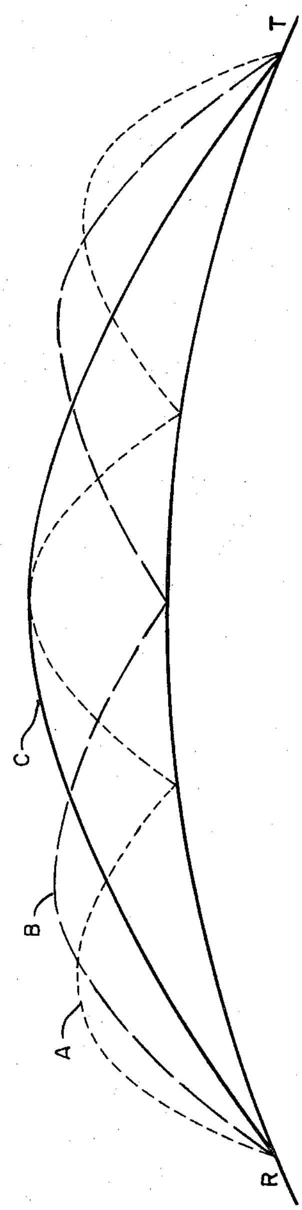
FIG. 2



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MULTI-DIRECTIONAL ANTENNA SYSTEM

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1 Claim. (Cl. 325—369)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment of any royalty thereon.

The present invention relates to a multi-directional antenna system and more particularly to a system for phasing the signals of the elements of an antenna array for transmitting or receiving a plurality of directional beams.

Known designs of receiving antenna arrays use tapped delay lines terminated with matched resistors for phasing the signals received by a plurality of antenna elements to obtain a multiplicity of beams. This design is wasteful because most of the energy of the received signals is dissipated in the matching resistors. If the received signals are first amplified before they are fed into the delay lines, the necessarily high output power of the amplifiers will make it difficult to keep the intermodulation distortion sufficiently low without deteriorating the signal to noise ratio of the antenna system. Also, the difficulty of obtaining wide frequency bandwidth of the amplifiers is compounded. Finally, phase errors are caused by tapped delay lines since each tap introduces a discontinuity in the line, however small, and thereby causes a reflection. The reflections from several taps will add in-phase for certain frequencies. It is extremely difficult therefore, to control the resulting phase errors in broadband systems using tapped delay lines.

It is therefore an object of the present invention to provide an antenna system wherein the intermodulation distortion is reduced while the signal to noise ratio is improved.

Another object of the invention is the provision of a phased antenna system having phasing components which will be accurate over a broad band of frequencies.

The exact nature of this invention as well as other objects and advantages thereof will be readily apparent from consideration of the following specification relating to the annexed drawings in which:

FIGURE 1 shows a circuit diagram of a preferred embodiment of the invention; and

FIGURE 2 illustrates three modes of travel for an RF wave when communicating between two distant points located on the earth's surface.

Referring now to the drawings there is shown in FIGURE 1 an antenna array made up of a plurality of antenna elements **10**, **11**, **12**, and **13** connected to the primary of transformers **14**, **15**, **16**, and **17** respectively. The secondaries of transformers **15**, **16**, and **17** are connected to delay lines **18**, **19**, and **20** respectively which in turn are connected to the primary windings of transformers **21**, **22** and **23** respectively. The secondary winding of transformer **14** is connected to the primary winding of transformer **24**. A set of three delay lines **25**, **26** and **27** of equal length are connected in parallel across the secondary winding of transformer **24**.

Transformers **21**, **22**, and **23** have connected in parallel across their secondary windings a set of three delay lines **28**, **29**, and **30**; **31**, **32**, and **33**; and **34**, **35**, and **36** respectively. The set of delay lines **28**, **29**, and **30**, associated with antenna element **11**, are progressively longer in length, with delay line **28** being the shortest, and delay line **30** being the longest of the set. Delay line **28** is equal in length to the delay lines **25**, **26**, and **27**. This is also

true for the length of delay line **31** and **34**. Delay lines **32** and **33** are each progressively longer than delay line **31** while delay lines **35** and **36** are each progressively longer than delay line **34**. The rate of increase in the length of the delay lines of each set gets greater as its associated antenna element is further removed from the element **10**. As can be seen in FIGURE 1 this is also true of the delay lines **18**, **19**, and **20**. The actual lengths of each delay line will be more accurately defined below.

Each of the delay lines **25–26** terminate in a matching transformer the secondary of which is connected to an amplifier. For example, the delay lines **31**, **32**, and **33** terminate in transformers **37**, **38**, and **39** respectively while the transformers are connected to amplifiers **40**, **41**, and **42**, respectively. Since all of the other sets of delay lines feed similar circuits they will not be described in detail.

All of the amplifiers which are associated with the first or shortest delay line (i.e. lines **25**, **28**, **31**, and **34**) of each set are connected to a receiver **43**. Receivers **44** and **45** are connected to the circuits including the second and third delay lines respectively of each set.

Before explaining the operation of the device of FIGURE 1, consider the paths shown in FIGURE 2. In long distance communication, it is the general practice to use a path, between the transmitter and the receiver which will include at least one reflection of the radio wave off the ionosphere and in some cases at least one reflection off the earth's surface. FIGURE 2 shows a transmitting station T and a distant receiver R located somewhere on the earth's surface. A radio wave transmitted from T to R could follow any one of the paths indicated by A, B, and C.

Of course, it is well known, that depending on the terrain between T and R, the time of day and year, and the existing ionospheric conditions, one of these paths will be superior to the others. It is therefore the general practice to find by trial and error, and use the path which will provide the least attenuation of the radio wave or otherwise most favorable condition.

The transmitted waves A, B, and C shown in FIGURE 2 will approach the receiver at the angles shown by the arrows A, B, and C of FIGURE 1. Of course, possibly only one antenna could be used to receiver any one of the signals; however, since any wave which has undergone several reflections will be attenuated to some degree, it will be desirable to use several antenna elements thereby increasing the efficiency along with providig the capability of rejecting undesirable signals from directions other than that of the desired signal. This rejecting of all other signals but the one desired is accomplished by phasing the antennas with the array of delay lines shown.

The object of the delay lines is to phase the signals received by elements **10–13** such that only signals from the desired direction will be in phase at a given receiver. Obviously, signals received from an undesirable direction will be out of phase at the receiver, thereby tending to cancel each other.

Assuming that signal A is traveling in the direction shown by the arrow A, element **13** will be the first element to receive the signal. This received signal will now be delayed by lines **20** and **34** before being amplified and transmitted to receiver **43**. Element **12** will next receive this same signal which will be delayed by lines **19** and **31**. The signal will be delayed by lines **18** and **28** when received by element **11**, and delayed by line **25** when received by element **10**. The delay due to the delay lines gets shorter for each element as the wave travels down the array. However, the total delay is equal for each signal received since there is a delay in time for the wave to travel between elements **13–12**, **12–11**, etc.

Because the angle between the horizontal and arrow A is large the travel time for the wave between the antenna elements will be small. The angle which arrow B makes with the horizontal is smaller thereby requiring a longer delay. Delay lines **26**, **29**, **32**, and **35** are intended to phase signals received from the direction B. Likewise, delay lines **27**, **30**, **33**, and **36** are intended to phase signals received from the direction C.

Of course, technically the length of delay lines **25**, **26**, **27**, **28**, **31** and **34**, which are all equal, may be reduced to zero with a similar adjustment in the other delay lines. However, it is assumed that the receiving equipment will be actually located some finite distance from the antenna elements thereby requiring some finite length for the delay line network. By the same token, equal lengths of delay lines may be added anywhere between the element and the receiver, if necessary.

The number of antenna elements could obviously be increased which will increase the efficiency of the device. Also, the number of delay lines in each set could be increased which would result in an increase in the number of directions in which signals could be received. The entire array obviously could be used for transmitting the directional beams A, B, and C by merely substituting transmitters for receivers **43**, **44**, and **45**, and making the usual adjustments for isolation and amplification.

It should be understood, of course, that the foregoing disclosure relates to only a preferred embodiment of the invention and that numerous modifications or alterations may be made therein without departing from the spirit and the scope of the invention as set forth in the appended claim.

What is claimed is:

A multi-directional antenna system comprising; a plurality of spaced antennas forming an array; each said antenna having an antenna feed means; a plurality of primary delay lines having differential lengths; each said antenna having a separate one of said primary delay lines at one end connected across said feed means; a plurality of sets of secondary delay lines; said secondary delay lines of each said set having different lengths; a plurality of transformers having primary and secondary coils; the other ends of each said primary delay lines being connected across said primary coil of a separate one of said transformers; each said set having one end of all said secondary delay lines therein connected in parallel with each other and connected across the secondary coil of a separate one of said transformer; a plurality of utilization devices; each said utilization device being coupled to the other end of a separate one of said secondary delay lines of all said sets; and the total delay between each said antenna and each said utilization device being such that signals received by said antennas from a plurality of directions will be in phase at a different utilization device.

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