June 3, 1969 J. K. PARKS 3,448,410

BROADBAND RECIPROCAL DUAL MEANDER LINE FERRITE PHASE SHIFTER

Filed May 25, 1967 Sheet 1 of 2

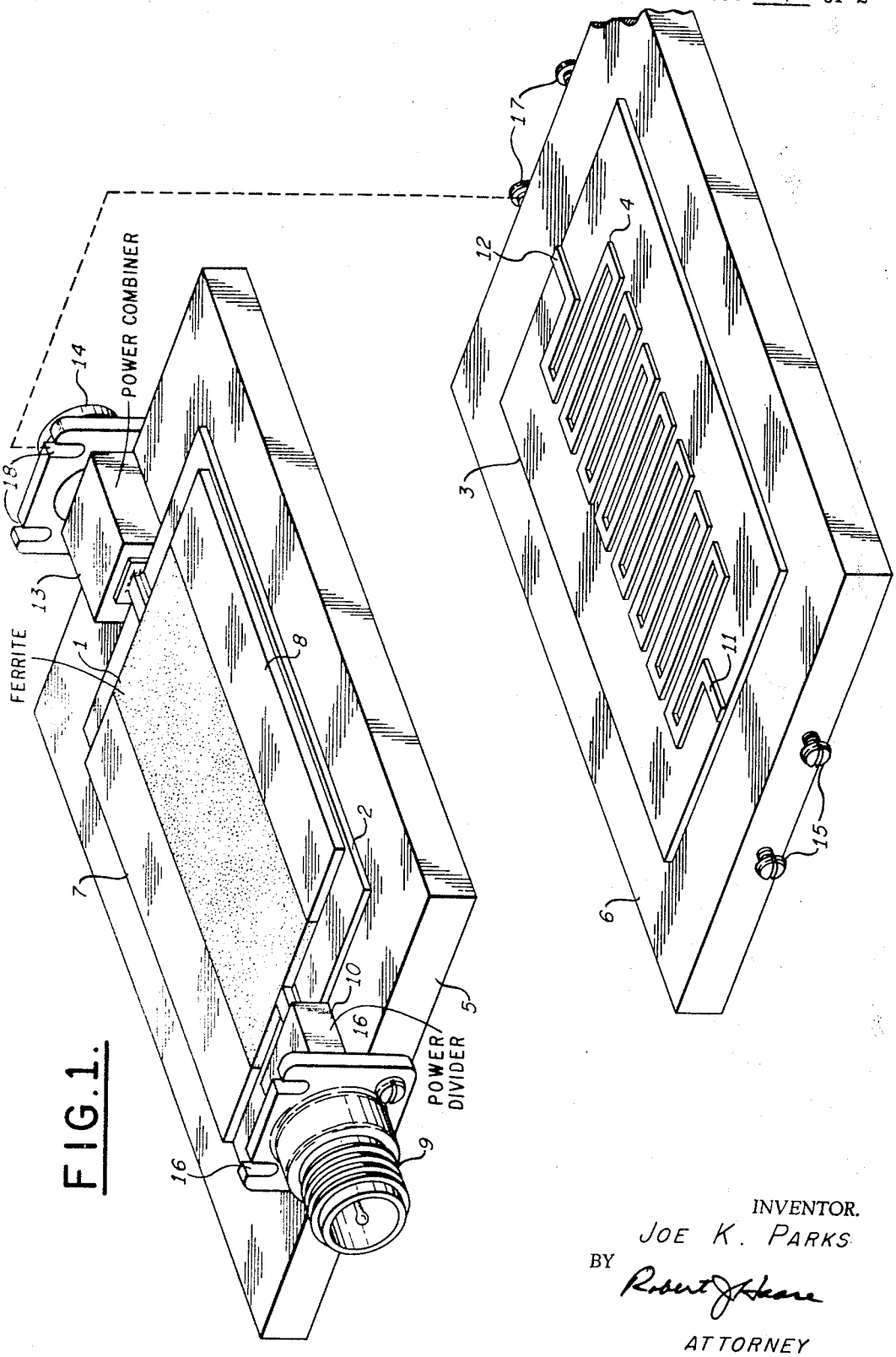


FIG. 1.

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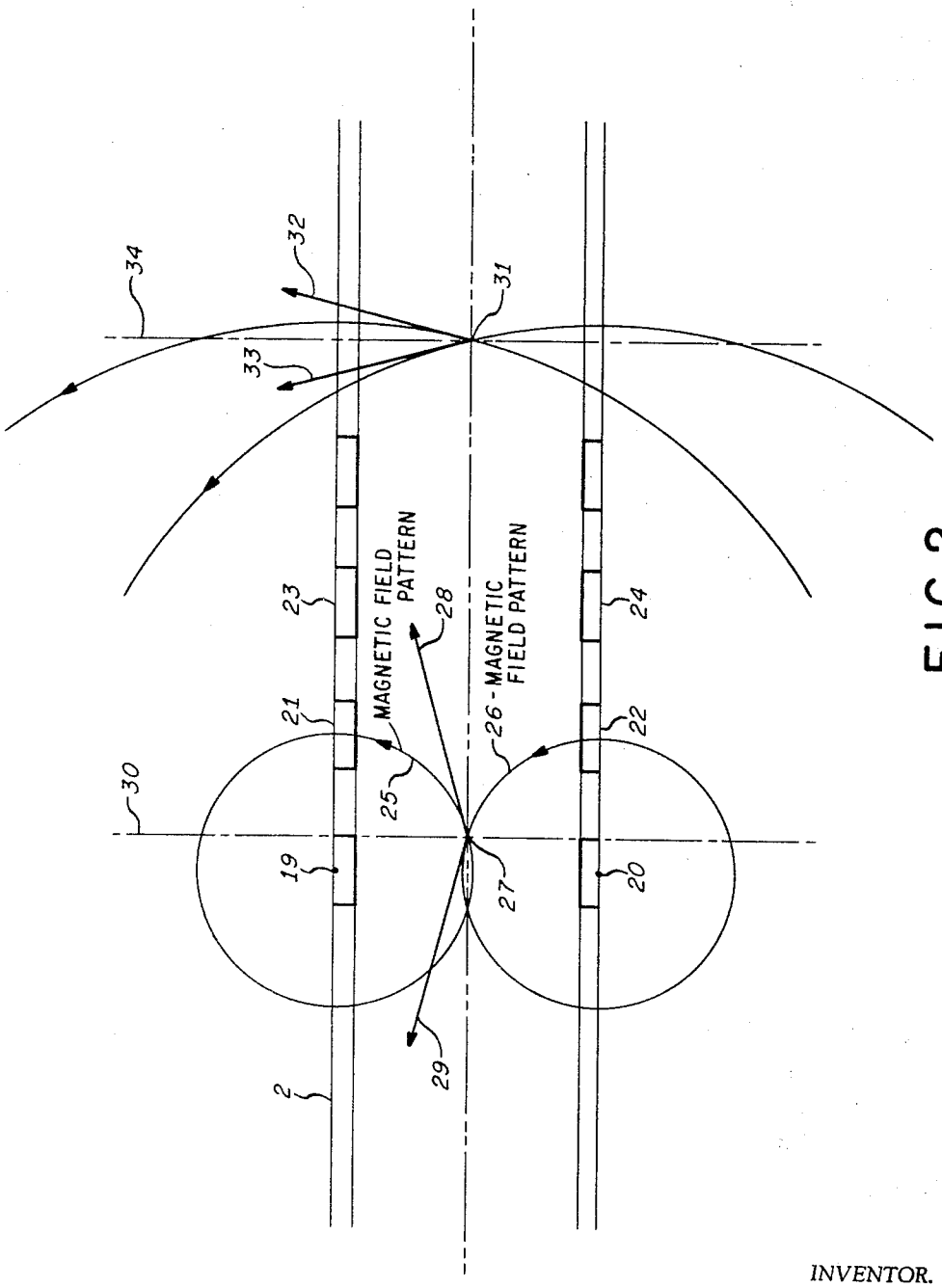


FIG. 2.

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BROADBAND RECIPROCAL DUAL MEANDER LINE FERRITE PHASE SHIFTER

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U.S. Cl. 333—31 4 Claims

ABSTRACT OF THE DISCLOSURE

A phase shifter having a reciprocal phase delay characteristic substantially independent of frequency comprising a pair of folded strip line (meander line) conductors parallel to each other with each line being mirror symmetric with respect to the facing side of the other line. A ferrite slab is located midway between the two meander lines. An input microwave signal is applied to one end of each of the lines with the same amplitude and the same phase. The other ends of the two lines are combined to provide a phase delayed output signal.

Background of the invention

The development of microwave devices continually is direction toward designs which provide minimum bulk and weight. Such designs are mandatory in the case of the complex electronic systems required in modern airborne applications. Among the various components required in airborne phased array radars, for example, broadband reciprocal phase shifters have presented a particularly difficult problem because of the large numbers which are involved. Compact ferrite phase shifter devices have been proposed utilizing strip line fabrication techniques but these either produce nonreciprocal amounts of phase shift or provide reciprocal phase shifts over only a very narrow frequency band.

Summary of the invention

Substantially purely reciprocal phase shift is achieved in a lightweight and compact device in accordance with the present invention by the provision of dual parallel meander lines which are excited with equal amplitude and equal phase microwave energy. Each meander line is mirror symmetrically identical to the facing surface of the other line. The resultant R.F. magnetic field midway between the two meander lines is substantially only linearly polarized in a direction perpendicular to the planes of the lines. This magnetic field orientation is preserved irrespective of the frequency of the microwave signal. A ferrite slab, placed in the region of the resultant linearly polarized R.F. magnetic field, introduces the same phase delay in the R.F. energy propagating along the meander lines independent of the direction of propagation.

Brief description of the drawings

FIGURE 1 is a perspective view of a partially disassembled embodiment of the invention; and

FIGURE 2 is a sketch of the R.F. magnetic field configuration within the embodiment of FIGURE 1.

Description of the preferred embodiment

Referring to FIGURE 1, a ferrite slab **1** is positioned between a pair of meander lines formed on insulating boards **2** and **3**. The meander line on board **2** (hidden from view) is mirror symmetrically identical to meander line **4** and board **3** so that the facing surfaces of the meander lines precisely match each other in every respect. It is convenient to form the meander lines by etching copper clad insulating boards in a conventional manner.

Insulating boards **2** and **3** are mounted on conductive slabs **5** and **6**, respectively. Two strips of dielectric material **7** and **8** are mounted on board **2** on respective sides of ferrite slab **1**. Strips **7** and **8** have the same thickness and length as slab **1**. Input microwave energy is supplied via coaxial line coupler **9** and matching transformer and power divider **10** to the input terminals (such as terminal **11** of line **4**) of the meander lines with the same amplitude and phase. An identical matching transformer and power divider **13** is coupled to the output terminals (such as terminal **12**) of the meander lines for combining the delayed signals and applying the same to output coaxial line coupler **14**. The phase shifter of FIGURE 1 is structurally and operationally symmetric with respect to its input and output ports. The phase shifter is assembled by mounting slab **6** across coaxial line couplers **9** and **14** with meander line **4** facing ferrite slab **1** and screws **15** engaging slots **16** in coupler **9** and screws **17** engaging slots **18** in coupler **14**.

Reciprocal phase shift is achieved in the embodiment of FIGURE 1 by producing a resultant R.F. magnetic field, in response to the flow of microwave energy along the dual meander lines, which is substantially linearly polarized in a direction perpendicular to the planes of the meander lines at a location substantially midway therebetween. The production of the aforesaid magnetic field orientation can be understood by reference to FIGURE 2 which is similar to a longitudinal sectional view of FIGURE 1. The ferrite slab has been omitted from FIGURE 2 in order to avoid confusion with the draftsman's construction lines depicting the magnetic field configuration. As previously mentioned, the meander lines are fed by microwave energy of the same amplitude and same phase so that the amplitudes and phases are the same at corresponding points of the lines such as points **19**, **20** and **21**, **22** and **23**, **24** and so on. Assuming that the direction of microwave current through points **19** and **20** of the respective meander lines momentarily are toward the observer in the view of FIGURE 2, circular magnetic field patterns **25** and **26** intersect at a point of interest **27** along a plane parallel to and equally distant between the meander lines. Tangents **28** and **29** (drawn to the respective field patterns **25**, **26**) are of equal amplitude and time phase and are equally angularly displaced with respect to line **30** which is perpendicular to the meander lines and passes through point **27**. It can be seen that although it varies in amplitude and sense, the vector resultant of magnetic fields **28** and **29** always lies along line **30** irrespective of the time phase of the microwave energy flowing through points **19** and **20** of the meander lines.

A similar graphical construction has been made about a second arbitrarily selected point of interest, point **31**, along the plane which is equally distant between the meander lines. Vector **32** represents the amplitude and direction of the magnetic field attributable to the current flowing through point **19** whereas vector **33** represents the magnetic field at point **31** attributable to the current flowing through point **20**. It will be noted that the angular displacement between the magnetic field component vectors is reduced as the distance increases between the point of interest and points **19** and **20**. However, the resultant magnetic field vector still lies along a line (**34**) which is perpendicular to the meander lines. Thus, the resulting magnetic field at any point along a plane which is equally distant from the meander lines is substantially linearly polarized in a direction perpendicular to the meander lines irrespective of the frequency of the microwave signal flowing through the meander lines. This follows from the fact that the magnetic field contributions at points **27** and **31** and at all other points along the same plane attributable

to currents flowing through points **21** and **22** and through points **23** and **24** and all other corresponding pairs of points likewise produce a resultant linearly polarized magnetic field as shown in the constructions relating to the currents flowing through points **19** and **20**. The resultant linearly polarized magnetic field provided by the dual meander line configuration of the present invention requires only that said lines be mirror symmetrically identical and be fed with microwave energy of the same amplitude and phase.

Ferrite slab **1** is placed in the position of the plane containing points **27** and **31** and introduces the same phase delay in the microwave signal propagating along the meander lines for either direction of propagation whereby the phase delay characteristic is reciprocal. Reciprocity is maintained irrespective of the frequency of the microwave signal. The magnitude of the phase delay is a function of the magnitude of the total magnetic field; accordingly, the phase delay may be controlled by means of a variable D.C. magnetic field which may be provided for biasing ferrite slab **1** in a conventional manner.

While the invention has been described in its preferred embodiment, it is to be understood that the words which have been used are words of description rather than limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

I claim:

1. A broadband reciprocal phase shifter comprising:
a ferromagnetic material containing a given plane,
said material being adapted to be biased by a D.C. magnetic field, and
means for producing an alternating magnetic field substantially linearly polarized irrespective to the frequency of said field, the direction of polarization of said field being perpendicular to said plane, said means comprising:
a pair of folded strip meander lines parallel to said plane and equally distant therefrom,
each of said lines being mirror symmetrically identical to the facing side of the other line,
means for applying an input alternating signal to one end of each of said lines with the same amplitude and phase, and
means for combining the other ends of said lines to provide an output port for said input signal.

2. Apparatus as defined in claim **1** wherein said ferrimagnetic material is a ferrite slab.

3. Apparatus as defined in claim **1** and further including a pair of insulating boards on which said lines are respectively mounted, each said board being on the side of its respective line opposite the side facing said given plane.

4. Apparatus as defined in claim **3** and further including a pair of conductive slabs on which said boards are respectively mounted, each said slab being on the side of its respective board opposite the side facing said given plane.

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