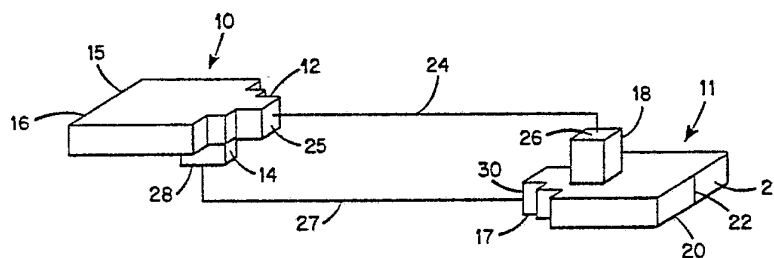




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(21) International Application Number: PCT/US81/00238 (22) International Filing Date: 25 February 1981 (25.02.81) (31) Priority Application Number: 124,619 (32) Priority Date: 25 February 1980 (25.02.80) (33) Priority Country: US (71) Applicant; and (72) Inventor: SALZBERG, Edward [US/US]; 19 Black Oak Rd., Wayland, MA 01778 (US). (74) Agent: TARRANT, Thomas, N.; 917 Elm Street, Manchester, NH 03101 (US).		(81) Designated States: DE (European patent), FR (European patent), GB (European patent), JP, NL (European patent), SE (European patent). Published <i>With international search report</i> <i>With amended claims</i>

(54) Title: MICROWAVE HYBRID COUPLERS



(57) Abstract

Microwave hybrid coupler combinations using magic tees (10, 11) in which the symmetrical arms (15, 16, 20, 21) are used for output ports in power combining and the nonsymmetrical arms (12, 14, 17, 18) are used for output ports in power dividing.

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MICROWAVE HYBRID COUPLERSBACKGROUND OF THE INVENTION:1. Field of the Invention:

Present invention relates to microwave hybrid tee
junctions connected in combination and particularly to
such combinations in which the symmetrical arms are
used for output connections in power combining and non-
symmetrical arms are used for output connecting in power
dividing.

2. Description of the Prior Art:

Magic tees, because of their plane of symmetry, are
usually used as power dividers with the e or h ports as
the input and the symmetrical ports as the two outputs.
This is the most natural way to use the tees since the
output phase relationships are a clear 0 or 180 degrees,
and the output equality is essentially perfect. The tees
are also often used as power combiners in which case the
preferred choice for the two inputs is the symmetrical
ports since the input phase and split requirements are
clearly defined and easily realized. Previous patent
3,931,599 of the present inventor describes hybrid tee
junction combinations with the e and h plane arms providing
input, output functions. It has been considered undesirable
to use a magic tee as a power divider with the e and h ports
as outputs since it is difficult to obtain equal split in
the output and the output phase may track at some odd angle.
It is also uncommon to use the symmetrical ports as outputs
for a power combiner because of an apparent difficulty
in meeting the required input phases and amplitude require-
ments to get precise power combination.



Technical Bulletin No. 020774-1 of Electromagnetes Sciences Inc., Chamblee, Georgia, describes a power modulator in which a magic tee is used as a power divider and the power out is connected through the symmetrical arms to two phase shifters which drive a quadrature coupler. If one of the phase shifters is switched 180°, the output will change terminals and shift 90° in phase. The outputs of the quadrature coupler will always be 180° out of phase with each other.

10 SUMMARY OF THE INVENTION:

In accordance with the present invention it has been found that magic tees can be connected as power combiners with their symmetrical arms as the outputs and can be connected as power dividers with their non-symmetrical arms as the outputs without losing the quality of the magic tees as usually used. Thus it is an object of the invention to provide combinations of magic tee hybrid couplers connected as power divider/combiners in the reverse configuration. Further objects and features of the invention will become apparent upon reading the following description together with the drawing.



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BRIEF DESCRIPTION OF THE DRAWING:

Fig. 1 is a drawing in perspective of two magic
tees joined in accordance with the invention.

5 Fig. 2 is a schematic diagram showing a second
embodiment of the invention in which 2 magic tees are
coupled together by two phase shifters.

Fig. 3 is a front elevation of four magic tees
interconnected in an embodiment according to Fig. 2
using magic tees coupled to phase shifting devices as
10 phase shifters.

Fig. 4 is a schematic diagram of the embodiment
of Fig. 3.

Fig. 5 is a bottom view along 5-5 of Fig. 3 with
two shorted waveguide stubs operating as a tracking
15 line, replacing one diode assembly in a third embodiment.

Fig. 6 is a modification of Fig. 5 in which one of
the shorted stubs is a different width.

Fig. 7 is a schematic diagram of an embodiment in
which one of the phase shifters has been replaced with
20 a tracking line.



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DESCRIPTION OF THE PREFERRED EMBODIMENT:

Fig. 1 is an embodiment of the invention using two h-plane folded magic tees 10 and 11. Tee junction 10 has h arm 12 and e arm 14 as nonsymmetrical arms. Symmetrical arms 15 and 16 are folded in the h plane with a common dividing wall (not shown) separating them. Similarly, tee junction 11 has an h arm 17 and e arm 18 as nonsymmetrical arms and arms 20 and 21 separated by common wall 22 as symmetrical arms. In the magic tee junction, the symmetrical arms are colinear, however, in many applications today the symmetrical arms are folded in the e plane or in the h plane. In Fig. 1 the symmetrical arms are shown folded in the h plane. The configuration of the symmetrical arms is not significant to the invention and they may be folded at either plane or not folded at all. It is critical to simplicity of design in the present invention that the junctions used in combination be as nearly alike as possible.

Connection 24 connects port 25 of h arm 12 to port 26 of e arm 18. Connection 27, identical to connection 24, connects port 28 of e arm 14 to port 30 of h arm 17. Thus all of the nonsymmetrical arms are interconnected leaving only the symmetrical arms available for input, output connections. Connections 24 and 27 are preferable substantially identical wave guide connections. It will be noted that while each of junctions 10 and 11 lacks symmetry at two of its ports, the combinations of the two junctions as connected in Fig. 1 considered as a single



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junction is completely symmetrical with respect to all four available ports.

In Fig. 1 with an input at one of arms 15 and 16, magic tee 10 is acting as a power divider having its output at the nonsymmetrical arms e arm 14 and h arm 12. By connecting these outputs to the nonsymmetrical arms of magic tee 11, magic tee 11 acts as a power combiner providing its output at one of the symmetric arms 20 and 21. This entire configuration is symmetric as a combination so that placing identical things into connecting lines 24 and 27 will not affect the symmetry. For a given input at arms 15 and 16, the output at arms 20 and 21 can be changed, such as switching from one port to the other, by phase shifters in lines 24 and 27. Thus Fig. 2 shows a magic tee 42 in the place of magic tee 11 of Fig. 1. Phase shifter 19 is located in connecting line 24 and phase shifter 23 is located in connecting line 27.

While many alternatives are available for phase shifters 19 and 23, one arrangement that works out well is depicted schematically in Fig. 4 in which phase shifters 19 and 23 are depicted as magic tees 35 and 38 respectively each with diode phase shifting devices. Thus the entire combination can be put together with 4 identical magic tees which are depicted in Fig. 3 as wave guide magic tees all using the folded h plane configuration of magic tees 10 and 11 (Fig. 1).



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Using four magic tees, the e arms are connected to e arms and the h arms are connected to h arms while still retaining complete symmetry. Tee junction 31 has its h arm 32 connected to h arm 34 of tee junction 35. E arm 5
36 of junction 31 is connected to e arm 37 of junction 38. H arm 40 of junction 38 is connected to h arm 41 of junction 42. E arm 44 of junction 42 is connected to e arm 45 of junction 35. Thus again all nonsymmetrical arms are interconnected with each other. The configuration
10 of Fig. 3 as can be seen in the illustration, lends itself readily to direct coupling of the nonsymmetrical arms. Minimal interconnecting adaptation is needed and a very compact configuration can be produced.

The symmetrical arms of junction 31 terminate in
15 ports 46 and 47. The symmetrical arms of junction 35 terminate in ports 48 and 50. The symmetrical arms of junction 38 terminate in ports 51 and 52 and the symmetrical arms of junction 44 terminate in ports 54 and 55. Thus eight ports are available for connection purposes. Using
20 tees 35 and 38 as phase shifters, impedance switching devices are connected at ports 48, 50, 51, and 52.

Fig. 4 schematically depicts diode switching devices connected to these ports, this leaves ports 46, 47, 54 and 55 available for input, output connections. A truth
25 table for the embodiment of Figs. 3 and 4 is provided in table 1 to illustrate the functions available from this type of device.



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In table I, "Feed" indicates the input port of tee junction 31, port 46 of 47 to which an input signal is fed. "Bias" indicates whether the diodes indicated are forward or reversed biased, + indicating forward and - indicating reverse. "Power output" indicates which of symmetrical arms 54 and 55 provides the output power, and "Relative Phase" is the comparison of phase at the feed as compared with the power output terminal.



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TABLE I

<u>FEED</u>	<u>59</u>	<u>BIAS</u>		<u>60</u>	<u>POWER</u> <u>OUT</u>	<u>RELATIVE</u> <u>PHASE</u>
		<u>57</u>	<u>58</u>			
46	-	+	+	-	55	0
46	+	-	-	+	55	180
46	+	-	+	-	54	0
46	-	+	-	+	54	180
47	-	+	+	-	54	0
47	+	-	-	+	54	180
47	+	-	+	-	55	0
47	-	+	-	+	55	180



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Figs. 5, 6 and 7 depict alternative arrangements in which only one controllable phase shifter is used. Fig. 5 depicts one such arrangement as it would be in a bottom plan view of Fig. 4. In this case ports 51 and 52 are coupled to shorted wave guide sections instead of to diode switches. Connected to port 51 is a shorted piece of wave guide 61 having length L . Connected to port 52 is a shorted length of wave guide 62 having electrical length $L - 90^\circ$. The length $L - 90^\circ$ is a length that is electrically 90° shorter at the design frequency than the length L . Fig. 6 depicts a similar arrangement, but with a shorted wave guide 63 connected to port 52 somewhat narrower in the dimension W across its wide wall than shorted wave guide 61. This variation provides less frequency sensitivity over a broader frequency band than that of Fig. 5.

Truth table I still applies, but only that part of it that assumes no changes in biasing for diodes 58 and 60. Table I as used will depend on the length of the respective shorted wave guides. So that by way of example, terminal 51 can be considered as having the fixed condition of a forward biased diode 58. Terminal 52 can be considered as having the fixed condition of a reversed bias diode 60.



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Fig. 7 operates in exactly the same way as Figs. 5 and 6 except that magic tee 38 is replaced with a tracking line 56. The magic tees coupled to shorted waveguide stubs in Figs. 5 and 6 are tracking lines.

5 Tracking line 56 can also be a length of wave guide selected to have as near as possible electrical symmetry with tee junction 35. Since tracking line 56 can be mechanically dissimilar, electrical symmetry is harder to obtain as a matter of design but close approximations
10 can be reached. There are sometimes advantages in this type of arrangement, at least for packaging purposes.

Referring back to Fig. 2, phase shifters 19 and 23 may be continuously variable ferrite phase shifters or other known phase shifters useful in the microwave band.
15 Ferrite or other phase shifting devices may also be coupled to magic tees 35 and 38 instead of semiconductor diode devices. The magic tees can be planar tees as well as waveguide tees and coaxial configurations are also contemplated. Input tee 31 in Fig. 2 can be replaced with
20 other input devices and the configuration of two phase control devices driving the nonsymmetrical arms of a magic tee provides a power output in the symmetrical arms that shifts 0° to 180° in phase and switches from one port to the other when one of the input phase control devices is shifted
25 180° .



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It is significant that when using four magic tees as in Figs. 3 and 4, an input at any one of ports 46, 47, 54 and 55 will combine in one of the ports of the opposite tee with the other port of the opposite tee remaining perfectly isolated. This is true over the entire transmission band of the magic tee no matter how poorly designed the tees are providing their construction is identical. For this purpose it is critical that tees 31 and 42 be identical, but not necessarily identical to tees 35 and 38. It is desirable that tees 35 and 38 also be identical to each other.

While the invention has been described with respect to specific embodiments, variations within the skill of the art are contemplated and it is intended to cover the invention as set forth within the scope of the following claims.



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CLAIMS:

1. A microwave hybrid tee power divider/combiner combination comprising:

- 5 (a) a hybrid tee having two symmetrical arms terminating in first and second output ports, an E-plane arm and an H-plane arm;
- (b) a first phase shifter having a first input terminal and a first output terminal, said first output terminal connected to said E-plane as
- 10 an input; and,
- (c) a second phase shifter having a second input terminal and a second output terminal with the second output terminal connected to said H-plane arm as an input, whereby signals at said first
- 15 input terminal and said second input terminal can be selectively directed to said first and second output ports.
2. A microwave hybrid tee power divider/combiner according to claim 1 wherein at least one of said first phase
- 20 shifter and said second phase shifter selectively shifts phase at the design frequency in the fixed amount of 180° whereby output power can be switched between said first and second output ports.



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3. A microwave hybrid tee power divider/combiner according to claim 1 wherein at least one of said first phase shifter and said second phase shifter is continuously variable whereby signals at said first
5 input terminal and said second input terminal can be selectively divided between said first and second output ports.

4. A microwave hybrid tee power divider/combiner according to claim 1 further comprising a second
10 hybrid tee having two symmetrical arms terminating in a first input port and a second input port, a second E-plane arm and a second H-plane arm wherein said second H-plane arm connects to said first input terminal and said second E-plane arm connects to said
15 second input terminal.

5. A microwave hybrid tee power divider/combiner according to claim 4 wherein said first hybrid tee and said second hybrid tee are substantially identical, said first phase shifter and said second phase shifter
20 are substantially identical and connecting lines are balanced so as to provide symmetry.

6. A microwave hybrid tee power divider/combiner according to claim 1 wherein said first phase shifter and said second phase shifter comprise hybrid tees.



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7. A microwave hybrid tee power divider/combiner combination comprising:

- 5 (a) a first hybrid tee having two symmetrical arms terminating in first and second input ports an E-plane arm and an H-plane arm terminating in first and second output ports respectively;
- (b) a second hybrid tee having two symmetrical arms terminating in second and third output ports, an E-plane arm and an H-plane arm terminating in 10 third and fourth input ports respectively;
- (c) a controllable phase shifter connected between one of said first and second output ports and the respective one of said third and fourth input ports; and,
- 15 (d) a fixed phase shift connection between the remaining one of said first and second output ports and the remaining one of said second and third ports that has similar response characteristics to said phase shifter over the design frequency 20 band.
8. A microwave hybrid tee power divider/combiner combination according to claim 7 wherein said first hybrid tee, said second hybrid tee and said phase shifter all comprise substantially identical hybrid 25 tee devices.



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9. A microwave hybrid tee power divider/combiner combination according to claim 8 wherein said fixed phase shift connection is a fourth hybrid tee having first and second symmetrical arms terminated with first and second lengths of shorted wave guide.
- 5
10. A microwave hybrid tee power divider/combiner combination according to claim 9 wherein said first length of shorted wave guide is electrically 90° longer at the center design frequency than said second length of shorted waveguide.
- 10
11. A microwave hybrid tee power divider/combiner combination according to claim 10 wherein the width of one of said first and second lengths of shorted wave guide is substantially less than the width of the other.
- 15
12. A microwave hybrid tee power divider/combiner according to claim 7 wherein said fixed phase shift connection is a tracking line.



13. The combination of microwave hybrid junctions comprising:

(a) a plurality of substantially identical hybrid junctions each having two symmetrical arms, and two nonsymmetrical arms, each arm terminating in a port;

(b) a plurality of connections connecting each port of each nonsymmetrical arm directly to a port of another nonsymmetrical arm at a different one of said hybrid junctions.

14. A combination of microwave hybrid junctions according to claim 13 comprising two hybrid junctions in each of which the two symmetrical arms consist of an E-plane arm and an H-plane arm with the E-plane arm of one of said junctions connected to the H-plane arm of the other junction and the E-plane arm of the other junction connected to the H-plane arm of the one of said junctions.

15. A combination of microwave hybrid junctions according to claim 13 wherein said hybrid junction consist of 4 hybrid junctions in which each of the nonsymmetrical arms are connected to a like nonsymmetrical arm of another of said junctions.



16. A combination of microwave hybrid junctions according to claim 15 wherein said hybrid junction comprises a first junction, a second junction, a third junction and a fourth junction, the nonsymmetrical arms of each junction consisting of one E-plane and one H-plane arm and wherein the E-plane arm of said first junction is directly coupled to the E-plane arm of said second junction, the H-plane arm of said first junction coupled to the H-plane arm of said third junction, the E-plane arm of said third junction is directly coupled to the E-plane arm of said fourth junction and the H-plane arm of said fourth junction is directly coupled to the H-plane arm of said second junction.
17. A combination of microwave hybrid junctions according to claim 16 wherein the symmetrical arms of said second junction and said third junction are each terminated with a switchable phase shift device.
18. A combination of microwave hybrid junctions according to claim 17 wherein each said switchable device is semiconductor diode and further comprising biasing supplies for selectively biasing said diodes into low or high impedances conditions to effectively change the reflection point of energy at the design frequency in the respective arm.



AMENDED CLAIMS

(received by the International Bureau on 3 July 1981 (03.07.81))

1. A microwave hybrid tee transfer switch using magic tee hybrid couplers comprising:

(a) a first hybrid tee having two symmetrical arms terminating in first and second output ports, an E-plane arm and an H-plane arm;

(b) a second hybrid tee having two symmetrical arms terminating in first and second input ports, an E-plane arm and an H-plane arm;

(c) a variable phase shifter connected between the E-plane arm of one of said first hybrid tee and said second hybrid tee and the H-plane arm of the other; and,

(d) a phase shifting device connected between the H-plane arm of said one and the E-plane arm of said other, whereby microwave power fed to one of said input ports can be fed to one of said output ports and switched between said output ports by varying said variable phase shifter.

2. A microwave hybrid tee transfer switch according to claim 1 wherein at least one of said first phase shifter and said second phase shifter selectively shifts phase at the design frequency in the fixed amount of 180° whereby output power can be switched between said first and second output ports.



3. A microwave hybrid tee transfer switch according to claim 1 wherein at least one of said first phase shifter and said second phase shifter is continuously variable whereby signals at said first input port and said second
- 5 input port can be selectively divided between said first and second output ports.
4. A microwave hybrid tee transfer switch according to claim 1 wherein said first hybrid tee and said second hybrid tee are substantially identical, said first phase shifter and said second phase shifter are substantially
- 5 identical and connecting lines are balanced so as to provide symmetry.
5. A microwave hybrid tee transfer switch according to claim 1 wherein said first phase shifter and said second phase shifter comprise hybrid tees.



6. A microwave hybrid tee power divider/combiner combination comprising :

- 5 (a) a first hybrid tee having two symmetrical arms terminating in first and second input ports, an E-plane arm and an H-plane arm terminating in first and second output ports respectively;
- 10 (b) a second hybrid tee having two symmetrical arms terminating in second and third output ports, an E-plane arm and an H-plane arm terminating in third and fourth input ports respectively;
- (c) a controllable phase shifter connected between the E-plane arm of one of said first hybrid tee and said second hybrid tee and the H-plane arm of the other; and,
- 15 (d) a fixed phase shift connection between the remaining E-plane arm and the remaining H-plane arm, said connection having similar response characteristics to said phase shifter over the design frequency band.



7. A microwave hybrid tee power divider/combiner combination according to claim 6 wherein said first hybrid tee, said second hybrid tee and said phase shifter all comprise substantially identical hybrid tee devices.
8. A microwave hybrid tee power divider/combiner combination according to claim 7 wherein said fixed phase shift connection is a fourth hybrid tee having first and second symmetrical arms terminated with first and second lengths of shorted wave guide.
- 5 9. A microwave hybrid tee power divider/combiner combination according to claim 8 wherein said first length of shorted wave guide is electrically 90° longer at the center design frequency than said second length of shorted wave guide.
10. A microwave hybrid tee power divider/combiner combination according to claim 9 wherein the width of one of said first and second lengths of shorted wave guide is substantially less than the width of the other.
11. A microwave hybrid tee power divider/combiner according to claim 6 wherein said fixed phase shift connection is a tracking line.



12. A combination of microwave hybrid junctions comprising:

- 5 (a) first, second, third and fourth substantially identical hybrid junctions each having two symmetrical arms and two nonsymmetrical arms the nonsymmetrical arms of each junction consisting of one E-plane and one H-plane arm;
- 10 (b) a plurality of connections coupling the E-plane arm of said first junction directly to the E-plane arm of said second junction, the H-plane arm of said first junction to the H-plane arm of said third junction, the E-plane arm of said third junction directly to the E-plane arm of said fourth junction and the H-plane arm of said fourth junction directly to the H-plane arm of said second junction; and,
- 15 (c) a switchable phase shift device terminating each of the symmetrical arms of said second junction and said third junction.



13. A combination of microwave hybrid junctions according to claim 12 wherein each said switchable device is a semiconductor diode and further comprising biasing supplies for selectively biasing said diodes into low or high impedance conditions to effectively change the reflection point of energy at the design frequency in the respective arm.
- 5



EDITORIAL NOTE

The claims amended by the applicant under Article 19 (1) of the PCT have not been renumbered in accordance with Section 205 of the Administrative Instructions under the PCT.

The following information is given hereafter in order to facilitate the understanding of the amended claims:

Correspondence between original and amended claims:

Original claims

1-3
4 (cancelled)

5
6-11
12
13-16 (cancelled)
17
18

Amended claims

1-3 (amended)

4 (new)
5 (amended)
6-11 (amended)

12 (amended)
13 (amended)

2 / 2

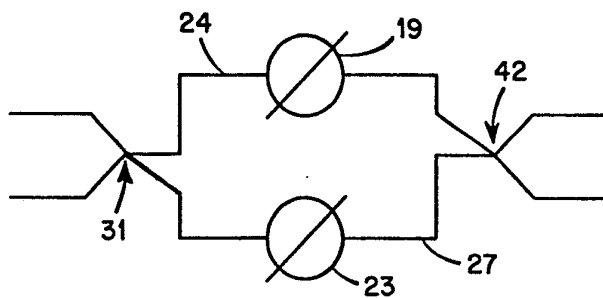


Fig. 2.

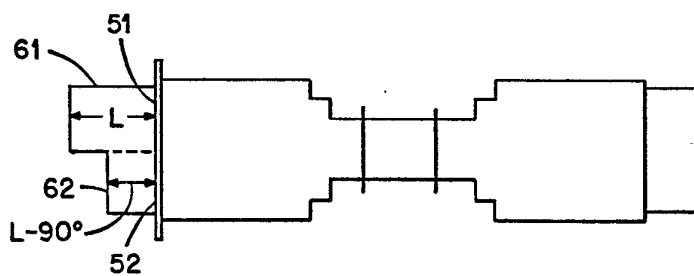


Fig. 5.

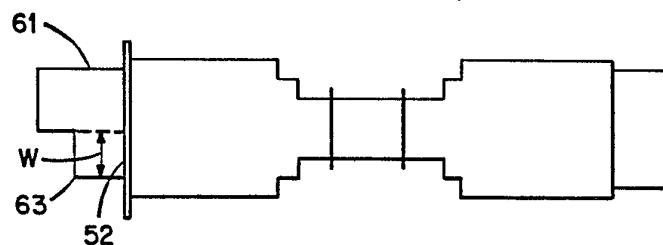


Fig. 6.

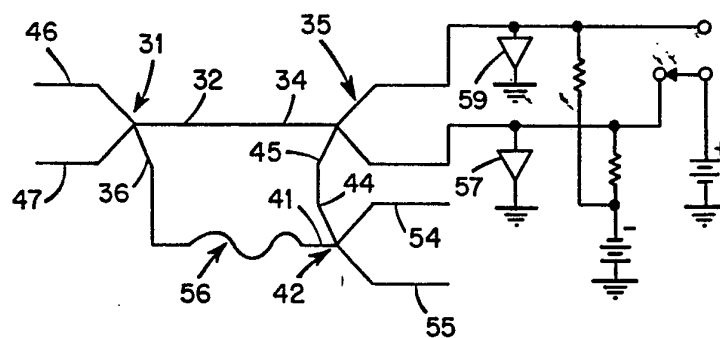


Fig. 7.

SUBSTITUTE SHEET



INTERNATIONAL SEARCH REPORT

International Application No PCT/US81/00238

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³		
According to International Patent Classification (IPC) or to both National Classification and IPC Int. Cl. ⁵ H01P5/20 U.S. Cl. 333/122		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁴		
Classification System	Classification Symbols	
U.S.	333/117, 118, 121, 122	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴		
Category ⁶	Citation of Document, ¹⁵ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
X	US, A, 2,884,600, published 28 April 1959, Fox	1-5, 7, 12
X	US, A, 2,801,391, published 30 July 1957, Whitehead	1, 4-6, 13, 15, 16
A	US, A, 2,619,635, published 25 November 1952 Chait	1, 3
¹⁵ Special categories of cited documents: "A" document defining the general state of the art "E" earlier document but published on or after the International filing date "L" document cited for special reason other than those referred to in the other categories "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the International filing date but on or after the priority date claimed "T" later document published on or after the International filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention "X" document of particular relevance		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search ²	Date of Mailing of this International Search Report ²	
13 April 1981	05 MAY 1981	
International Searching Authority ¹	Signature of Authorized Officer ²⁰	
ISA/US	Paul Gensler	