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NASA CASE NO. NPO-14,810-1

PRINT FIG. 1

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(NASA-Case-NPO-14362-1) ANTENNA FEED SYSTEM  
FOR RECEIVING CIRCULAR POLARIZATION AND  
TRANSMITTING LINEAR POLARIZATION Patent  
Application (NASA) 13 p HC A02/MP A01

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ANTENNA FEED SYSTEM FOR RECEIVING CIRCULAR  
 POLARIZATION AND TRANSMITTING LINEAR POLARIZATION

This invention relates to an antenna feed system which accepts circular polarization in the receiving mode and transmits linear polarization in the transmit mode, without incurring polarization mismatch losses for deep space telecommunications with the uplink, and performing scientific investigations and engineering tasks with the downlink.

FIG. 1 discloses one embodiment in which an antenna feed (10) is connected to orthogonally spaced antenna elements (11, 12, 13, 14) and for transmitting a linearly polarized microwave signal through the same feed without switches, and without suffering a 3 dB polarization mismatch loss, using an arrangement of hybrid junctions. The arrangement is comprised of two 180° hybrid junctions (15, 16), each connected to a different pair of dramatically opposite antenna elements and a 90° hybrid junction (17). In this one embodiment, a receiver (18) is connected to the 90° hybrid junction directly. A diplexer (19a or 19b) is used to connect a transmitter (20a or 20b) to only one pair of antenna elements. In an alternative embodiment shown in FIG. 2, left and right circularly polarized (LCP and RCP) transmitters (21, 22) are connected to the 90° hybrid junction by separate diplexers (23, 24), and separate LCP and RCP sensitive receivers (25, 26) are connected to the diplexer in order to transmit linearly polarized microwave signals using all four antenna elements while receiving circularly polarized microwave energy as before. In a third embodiment, an orthomode coupler (30) and horn antenna (32) replace the two 180° hybrid junctions (15, 16) and antenna feed (10) in the embodiment of FIG. 1.

The novelty of the invention resides in the arrangement of elements, which are normally reciprocal in their receiving and transmitting operations, with diplexers in key positions to transmit half power with linear polarization, and to receive full power with circular polarization. Using two diplexers with two transmitters allows for linear polarization transmission with full power instead of half power. At the same time, two receivers may be connected for both right hand and left hand polarized signal reception.

ANTENNA FEED SYSTEM FOR RECEIVING CIRCULAR  
POLARIZATION AND TRANSMITTING LINEAR POLARIZATION

ABSTRACT

An object is to provide for receiving a circularly polarized signal from an antenna feed (10) connected to orthogonally spaced antenna elements (11, 12, 13, 14) and for transmitting a linearly polarized signal through the same feed without switches, and without suffering a 3 dB polarization mismatch loss, using an arrangement of hybrid junctions. The arrangement is comprised of two dividing hybrid junctions (15, 16), each connected to a different pair of antenna elements and a summing hybrid junction (17). In one embodiment, a receiver (18) is connected to the summing hybrid junction directly. A diplexer (19a or 19b) is used to connect a transmitter (20a or 20b) to only one pair of antenna elements. In an alternative embodiment, designated left and right circularly polarized (LCP and RCP) transmitters (21, 22) are connected to the summing hybrid junction by separate diplexers (23, 24), and separate LCP and RCP sensitive receivers (25, 26) are connected to the diplexers in order to transmit linearly polarized signals using all four antenna elements while receiving circularly polarized signals as before. An orthomode junction (30) and horn antenna (32) may replace the two dividing hybrid junctions (15, 16) and antenna feed (10).

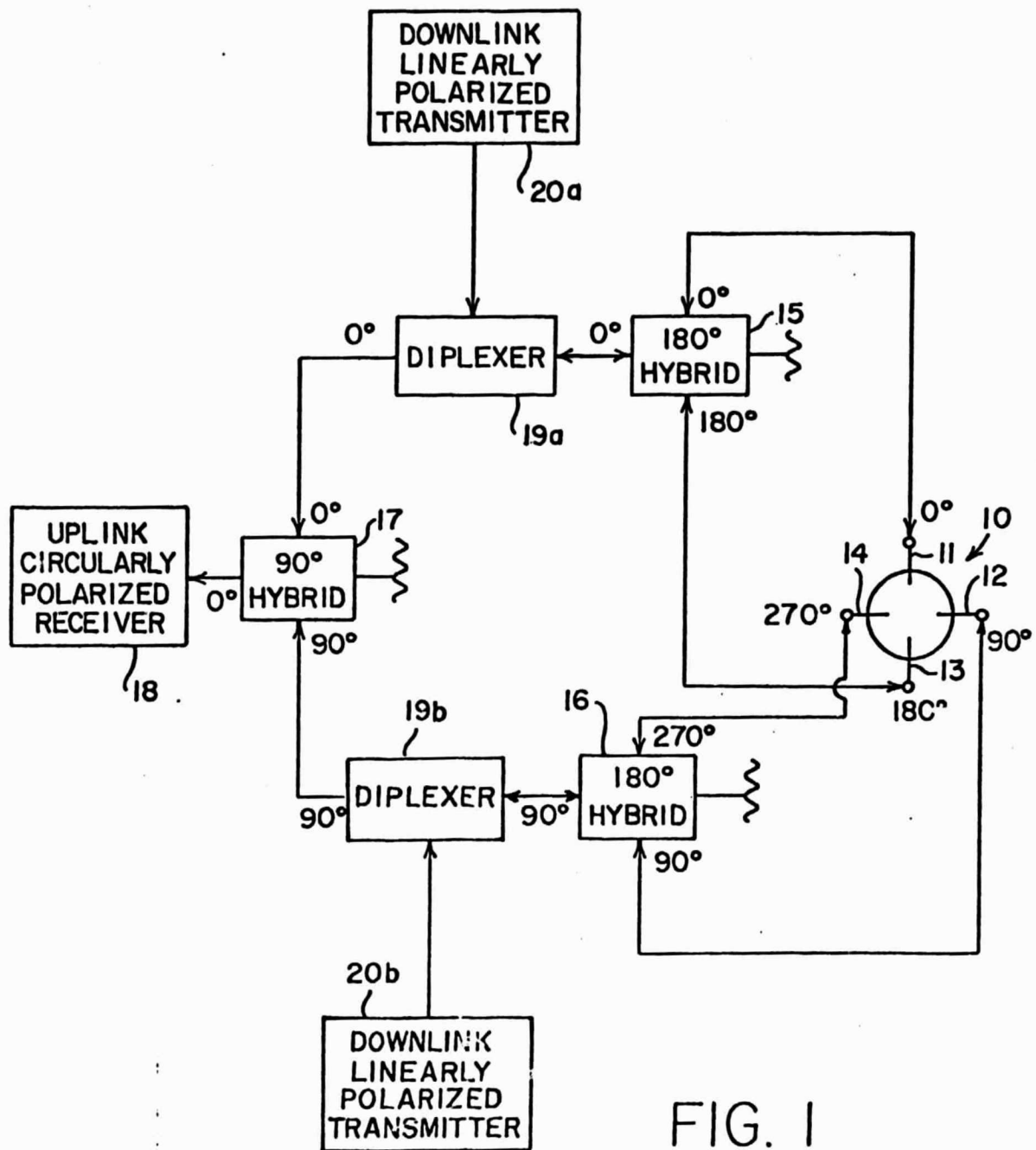


FIG. 1

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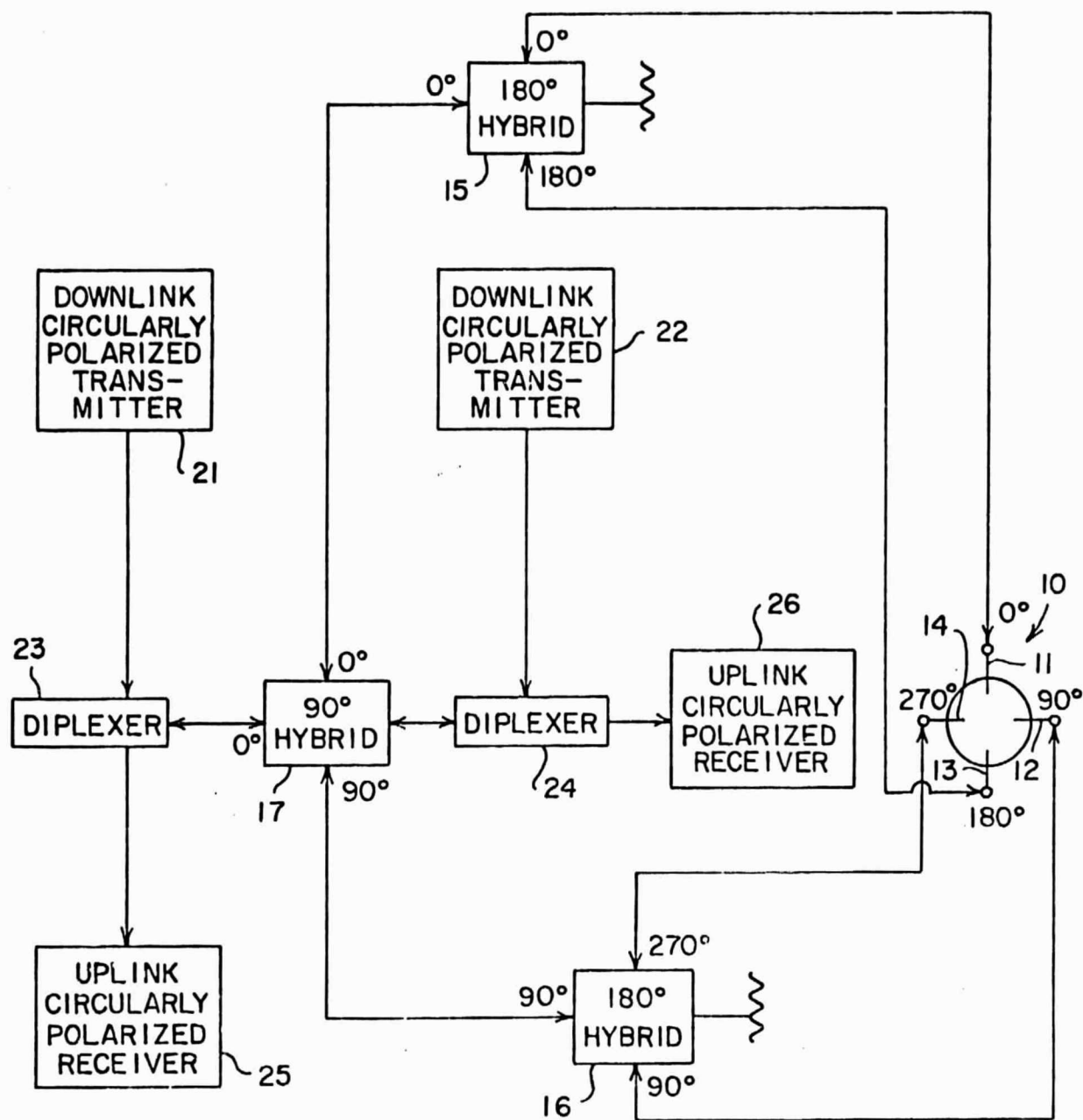


FIG. 2

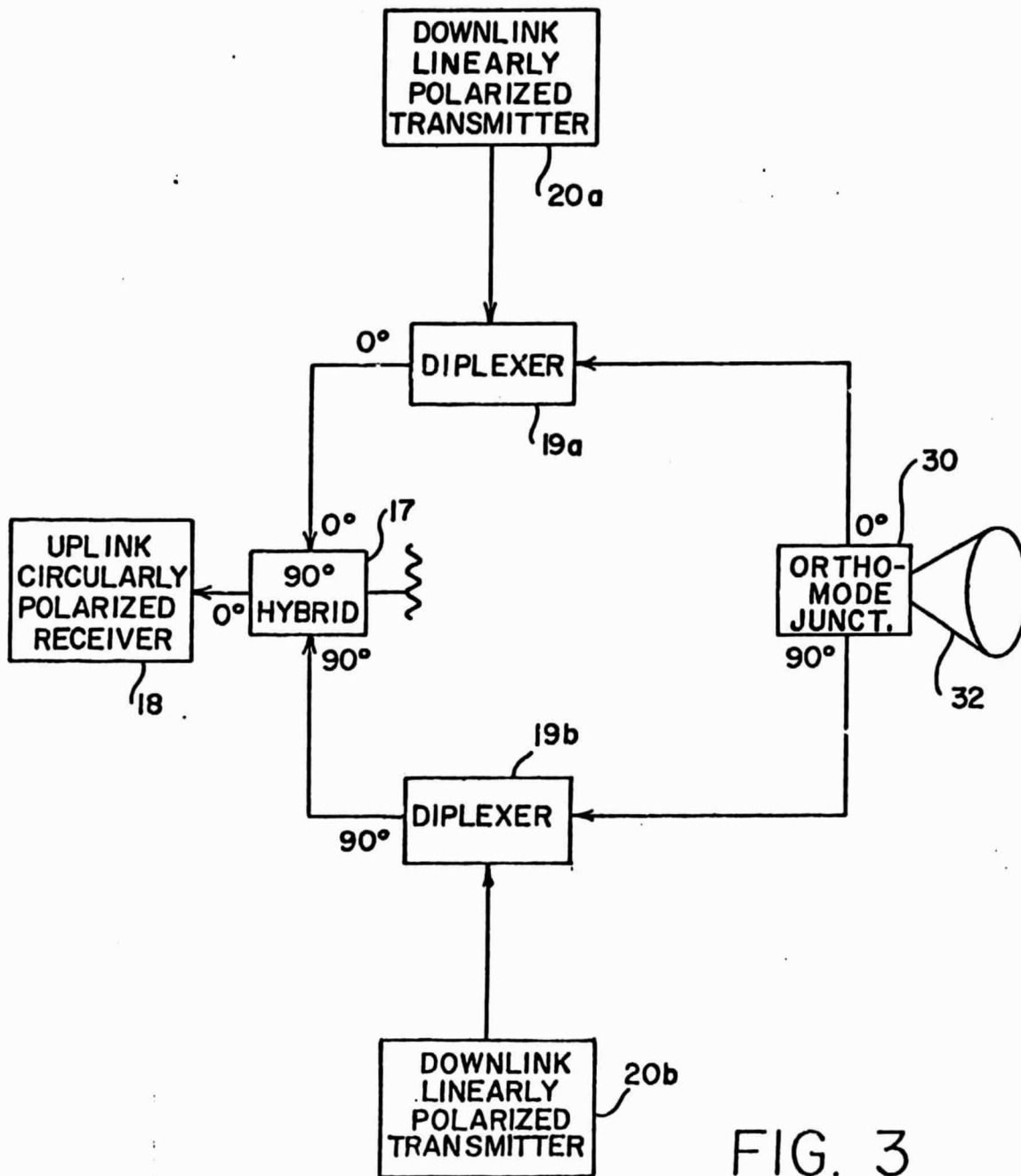


FIG. 3

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ANTENNA FEED SYSTEM FOR RECEIVING CIRCULAR  
POLARIZATION AND TRANSMITTING LINEAR POLARIZATION

Origin of Invention

The invention described herein was made in the  
5 performance of work under a NASA contract and is subject to  
the provisions of Section 305 of the National Aeronautics  
and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42  
USC 2457).

Technical Field

10 This invention relates to an antenna feed system  
which accepts circularly polarized signals while receiving  
and transmits linearly polarized signals.

Background Art

Most of the deep space telecommunications links  
15 use circular polarization. One reason for this is because  
of the operational simplicity of tracking a circularly  
polarized signal as opposed to a linearly polarized signal.  
However, linear polarization provides an opportunity to  
perform scientific investigations and engineering tasks  
20 that cannot be done with circular polarization. This being  
the case, for some space missions it would be desirable to  
have a downlink from the spacecraft that is linearly  
polarized. Since the Deep Space Network (DSN) normally  
radiates a circularly polarized uplink, it has been  
25 recognized that a penalty for providing a linear downlink  
would be 3 dB loss in the uplink due to polarization  
mismatch. An implementation that provides a linear  
downlink capability without suffering the 3 dB uplink loss  
is desirable.

30 The linearly polarized downlink on the spacecraft  
would provide an opportunity to conduct investigations,  
such as of the solar corona with Faraday rotation  
techniques. In addition, a linearly polarized downlink



would provide an opportunity for calibrating the Earth's ionosphere. The calibration of the ionosphere is needed by some deep space missions to provide precision navigation. Present ionospheric calibration methods are problematic  
5 (not line of sight) and use linearly polarized VHF satellites which are becoming less available. Use of a linearly polarized signal in the line-of-sight would be an attractive alternative, that is, use the same downlink for telemetry, ionospheric calibrations, and scientific  
10 investigations.

#### Statement of Invention

An object of this invention is to provide a system for transmitting a linearly polarized signal and for receiving a circularly polarized signal, without suffering  
15 a 3 dB polarization mismatch loss.

In its broadest aspects, an antenna capable of receiving a circularly polarized signal is connected to means for separating the signal into orthogonal linear components which are then recombined at the input to the  
20 receiver by a summing hybrid junction to present to the receiver the total power carried in the circularly polarized signal received at the antenna. A diplexer is used in at least one linearly polarized component path to permit transmission of a linearly polarized signal through  
25 the antenna. In one embodiment, each of two pairs of orthogonally disposed antenna elements are connected to separate ports of separate  $180^\circ$  hybrid junctions, each having a third port connected to the summing hybrid junction for receiving circularly polarized signals at the  
30 receiver. Due to the diplexer in the linearly polarized component path to which an active transmitter is connected, only one  $180^\circ$  hybrid is fed while transmitting. Both  $180^\circ$  junctions transfer linearly polarized signals that are orthogonal while receiving a circularly polarized signal.  
35 These linearly polarized signals are thus transferred to the summing hybrid junction which extracts all of the power

from the circularly polarized signal and couples it to the receiver. Thus, while receiving, the entire energy in the uplink circularly polarized wave at the antenna is coupled to the receiver.

5 In another embodiment, two transmitters are used, one transmitting a signal with right circular polarization, and the other transmitting a signal with left circular polarization. When both are transmitting simultaneously, the output results in transmission of a linearly polarized  
10 signal. If only one transmitter is excited, only right or left circular polarization is transmitted. Two receivers can be connected through diplexers to receive left and/or right circularly polarized signals.

The novel features that are considered  
15 characteristic of this invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in connection with the accompanying drawings.

#### Brief Description of Drawings

20 FIG. 1 illustrates one embodiment of the invention.

FIG. 2 illustrates an alternative embodiment of the invention.

25 FIG. 3 illustrates still another alternative embodiment.

#### Detailed Description of the Invention

Before referring to the schematic diagrams of the invention, several useful forms of hybrid junctions will be described, all of which are described in Radar Handbook  
30 edited by Merrill I. Skolnik and are widely used in microwave systems as power dividing and summing devices. One is the 3 dB directional coupler sometimes called a quadrature hybrid junction or coupler because it divides the power inserted in one port equally between two other

ports, with phase quadrature between the two output signals, and provides no power to the fourth port. Another is the magic-T hybrid junction which divides power inserted in one port equally between two other ports, with  $0^\circ$  or  $180^\circ$  phase difference between the two output signals, depending on which input port is used, and provides no power to the fourth port. A third is the hybrid ring which has four ports, 1, 2, 3 and 4, spaced electrically  $90^\circ$  apart, with an electrical spacing of  $270^\circ$  from port 4 to port 1 to complete a ring. A signal into port 1 divides equally with  $180^\circ$  phase difference between port 2 and port 4, and a signal into port 3 divides equally between ports 2 and 4 with zero phase difference.

In the schematic diagrams to be described, the hybrid junctions are represented by rectangles, each having four ports, with an indication of whether it is of the  $90^\circ$  phase difference type, namely a quadrature coupler, or of the  $180^\circ$  phase difference type, namely a magic-T or hybrid ring. In each case, the phase relationships of the ports are indicated, and an unused port is terminated by a suitable impedance to absorb any incidental energy out of that port. However, it should be understood that the invention is not limited to these particular hybrid junctions. The concept of the invention is given to any suitable implementation with due consideration to bandwidth and power handling capabilities.

Referring now to FIG. 1, an antenna feed 10 having orthogonally disposed antenna elements 11, 12, 13 and 14 are grouped in pairs, namely 11, 13 and 12, 14, for coupling through  $180^\circ$  hybrid junctions 15 and 16. The hybrid junctions 15 and 16 are, in turn, coupled by a  $90^\circ$  hybrid junction 17 to a receiver 18 for uplink circularly polarized reception. A diplexer 19a connects the hybrid junction 15 to a transmitter 20a for downlink linearly polarized signals by excitation of only elements 11 and 13. A diplexer 19b connects the hybrid junction 16 to a

transmitter 20b for downlink transmission of linearly polarized signals by excitation of only elements 12 and 14. Note that the two linearly polarized signals transmitted are orthogonal, so if both are excited simultaneously in phase quadrature, circular polarization could be achieved. However, in practice only one transmitter would be used for transmitting a linearly polarized signal. The other transmitter would serve as a back-up (with its transmission polarized in space orthogonal to the first transmitter).

10 This arrangement of hybrid junctions provides for a linearly polarized downlink transmission from a spacecraft while allowing the spacecraft to receive a circularly polarized uplink transmission. No switches are required to achieve linear transmit and circular receive operation either individually or simultaneously, and no spacecraft commands are required; the circular receive and transmit capabilities are inherently present for use at all times. All that is necessary besides the hybrid couplers is a diplexer for connecting the transmitter to the hybrid junction 15 (16), and for isolating the hybrid junction 17 connected to the receiver while transmitting

While receiving,  $180^\circ$  hybrid junctions 15 and 16 feed the summing hybrid junction 17, thereby coupling the circularly polarized uplink transmission to the receiver 18. The diplexer 19a automatically couples the hybrid junction 15 to the hybrid junction 17, with essentially no loss to the signal received and essentially no coupling to the transmitter 20a. While transmitting, the diplexer 19a couples the transmitter 20a to the hybrid junction 15 with essentially no loss of the signal transmitted and with essentially no coupling to the summing hybrid junction 17. The transmit power is simply divided once into signals  $180^\circ$  out of phase for excitation of the antenna elements 11 and 13. Operation for the diplexer 19b and transmitter 20b is similar.

The diplexer 19a is essentially a short circuit

between hybrid junctions 15 and 17 while receiving, and it is then convenient to view the reciprocal arrangement as transmitting, with the energy source assumed to be occupying the receiver position 18. The hybrid junction 17  
5 divides the assumed energy source into two signals  $90^\circ$  out of phase, and each signal is again divided into two signals  $180^\circ$  out of phase to thereby produce four signals of equal amplitude at the elements of the antenna feed 10 at phase angles of  $0^\circ$ ,  $90^\circ$ ,  $180^\circ$  and  $270^\circ$ . The signals from one  
10  $180^\circ$  hybrid junction are applied to one pair of diametrically opposite antenna elements, and the signals from the other  $180^\circ$  hybrid junction are connected to the other pair of diametrically opposite antenna elements. The result is a circularly polarized signal. With the receiver  
15 back in place, the reciprocal action of receiving the circularly polarized uplink signal results in all of the circularly polarized energy being delivered to the receiver. For transmitting the downlink signal, energy is made available to only one pair of antenna elements for a  
20 linearly polarized signal transmission. This arrangement thus provides a solution to the problem of providing a linearly polarized downlink and a circularly polarized uplink, without suffering a 3 dB polarization mismatch loss, and without switches and commands. The arrangement  
25 of hybrid junctions and a diplexer enables the polarization change without switches.

In the embodiment of FIG. 2, the hybrid junctions 15, 16 and 17 are connected to an antenna feed 10 for a circularly polarized uplink as in the embodiment of FIG. 1,  
30 and are therefore identified by the same reference numerals. What is different is that all four antenna elements are excited for a linearly polarized downlink signal using two transmitters 21 and 22 coupled to the  $90^\circ$  hybrid junction 17 by respective diplexers 23 and 24. A  
35 combination of a left circularly polarized (LCP) signal derived from connections associated with transmitter 21 and

a right circularly polarized (RCP) signal derived from connections associated with transmitter 22, for example, produces a linear polarization of the downlink signal. If only one transmitter is energized, all antenna elements will still be excited, but then a circularly polarized signal is transmitted, for example, LCP from transmitter 21 or RCP from transmitter 22. While receiving, a receiver 25 coupled to the  $90^\circ$  hybrid junction 17 is sensitive to, for example, RCP energy, and a receiver 26 coupled to the hybrid junction 17 is sensitive to, for example, LCP energy.

In a third embodiment shown in FIG. 3, an orthomode junction 30 and a horn antenna 32 effectively replace the  $180^\circ$  hybrid junctions 15 and 16, and the antenna feed 10, respectively, in the arrangements described above with reference to FIG. 1. The output of the orthomode junction while receiving is two orthogonal ( $0^\circ$  and  $90^\circ$ ) and  $90^\circ$  phase shifted linearly polarized signals which are the components of a circularly polarized uplink signal. The hybrid junction 17 combines the components and presents the total power to the receiver. The diplexer 19a is transparent to received signals, and couples the linear transmitter 20a to one port of the orthomode junction. The reciprocal action of the orthomode is then one of transmitting through the horn antenna a linearly polarized downlink signal. The diplexer 19b and transmitter 20b coupled to the other port of the orthomode junction transmit an orthogonal downlink to that of diplexer 19a and transmitter 20a.

Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and variations may readily occur to those skilled in the art. Consequently, it is intended that the claims be interpreted to cover such modifications and equivalents.