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A QUASI - OPTICAL TRANSMIT/ RECEIVE SWITCH FOR THE GOLDSTONE SOLAR SYSTEM RADAR

Raul Perez and Al Bhanji
Jet Propulsion Laboratory, California Institute of Technology

Abstract: *A novel quasi - optical transmit/receive switch design for use with a high transmit power, low receive noise planetary imaging radar system is described. Design tradeoffs and implementation are discussed,*

I. Introduction

The NASA / JPL Goldstone Solar System Radar (GSSR) [1] operates a 500 kW CW transmitter at 8.5 GHz in conjunction with MASER and HEMT cryogenically - cooled receivers at the same frequency. The transmit and receive systems use separate feedhoms to illuminate the sub - reflector of a 70 meter diameter azimuth - elevation Cassegranian antenna (fig. 1) The transmitted signal is circularly polarized in either sense (Right Hand Circular, Left Hand Circular), and reception is in both circular polarization senses simultaneously. This system is used for radar astronomy studies of all planets in the solar system, many planetary moons, and asteroids. The GSSR operates either with a CW transmit signal, or with a pseudo - random phase modulation on a CW carrier to provide correlation between the transmit and receive pulses. Due to the large antenna to target distances, involving round - trip light times of up to several hours, duplexing in this radar system has been achieved until recently by positioning the antenna sub - reflector to focus either on the transmit or receive feedhorn. This method eliminates the design problem presented by a conventional waveguide duplexer which would be required to carry 450 kW on one arm, while connected to a MASER receiver of 14.5 Kelvin noise temperature on the other.

Recent emphasis on the observation of near - Earth asteroids, with round - trip light times as short as 30 seconds present a difficulty in that the antenna sub - reflector requires approximately that amount of time to be re - positioned from the transmit to the receive position. Additionally, this causes a great deal of mechanical wear on the positioning mechanism of the 9 meter diameter, 3600 kg sub - reflector due to the high number of transmit / receive cycles that maybe performed while a near - Earth asteroid is visible in the sky. A high - power waveguide switch was implemented, with the intent of using the same feedhom for both transmit and receive operation, thus removing the need to re - position the sub - reflector. A HEMT receiver with a noise temperature of 29 Kelvin was used with this system. While promising, this method has suffered reliability problems due to the high CW power level, and the small mechanical clearances required to maintain RF isolation between the transmit and receive paths.

11. The Quasi - Optical Transmit / Receive Switch

Experience with quasi - optical transmission lines at high power levels [2] suggested the application of a quasi - optical switch to this duplexing problem. Using this method (fig. 2), the antenna sub - reflector is positioned to focus on the transmit feed for the duration of the observation, and transmit/ receive switching is accomplished by inserting a pair of shaped metallic mirrors in the receive path to image the receive feed at the transmit feed location during the receive cycle. This method presents the following system advantages:

1. Switch times in the order of one second, allowing radar imaging of asteroids inside a Lunar orbit.
2. Transmit power capacity is limited only by the transmitter waveguide and feed.
3. The receive mirror pair represents an additional degree of freedom which may be used to compensate for antenna main deflector errors of surface shape.
4. The receive mirror pair allows first - order cancellation of the cross - pole polarization component created in a single mirror due to axial illumination asymmetries [3]. This is of importance in the GSSR as significant science data is obtained from polarization reversal at the target.
5. The original system configuration of sub - reflector position duplexing for use with distant targets is available by switching the mirror pair away to the transmit position.
6. A decrease of receive signal noise temperature of approximately 13 Kelvin is realized for near - Earth targets through the use of the 14.5 Kelvin MASER received instead of the 29 Kelvin HEMT receiver.

111. Quasi - Optical Switch Design

The duplexing function performed by the Quasi - Optical switch would also be possible by routing the transmit signal though a mirror pair, thus imaging the transmit feed at the receive feed focus. This option was not implemented due to the possibility of substantial transmit power leakage past the mirror edges, and back lobes due to mirror edge currents. The implementation chosen resulted in approximately 0.25 dB gain loss on receive due to de - focusing and spillover losses (but not necessarily an increase in noise temperature).

The mirrors are paraboloids in shape, with a focal length of 25 cm, dictated by the transmit and receive horn separation. Mirror size was constrained by blockage and shadowing of existing equipment, and the requirement for low mass in one direction, and a -40 dB edge taper on the other to minimize the increase in receive noise temperature. Mirror surface shape optimization was accomplished using Physical Optics design codes,

IV. Implementation

A mechanical drawing, and picture of the finished Quasi - Optical T/R switch are found in figures 3 and 4, respectively. The moving portion of the framework, and mirrors, was constructed of aluminum to minimize the moving mass. The mirrors were fabricated. using Computer Numerical Control machining methods, The weight of the finished switch is close to 100 kg, The actuation system for movement of the switch employs a pneumatic cylinder and an electro - pneumatic interface to the radar controller. Hydraulic control was dismissed due tolikely contamination of antenna surfaces with working fluid, Drive with electric motors or solenoids was ruled out due to poor response times, and the incompatibility of electrical circuitry with the extremely high RF power densities present in the vicinity of the transmit feed, A precise system of bearings and clamps is employed to ensure the repeatable mechanical alignment of the mirrors to the feedhorns. The design mechanical life of this switch is several million transmit / receive cycles,

V. Status and Conclusion

The Quasi - Optical T/R switch was only recently installed within the GSSR antenna. To date, basic functional tests have been performed, but the switch has not yet been used in the imaging of a target. Results of operation will be published when sufficient data is available.

Quasi - Optical transmission systems of this type posses inherent advantages over conventional dominant - mode waveguide methods in applications involving high power, low loss, and high frequencies, which will result in widespread application in both ground and space - borne scientific instruments and communication systems,

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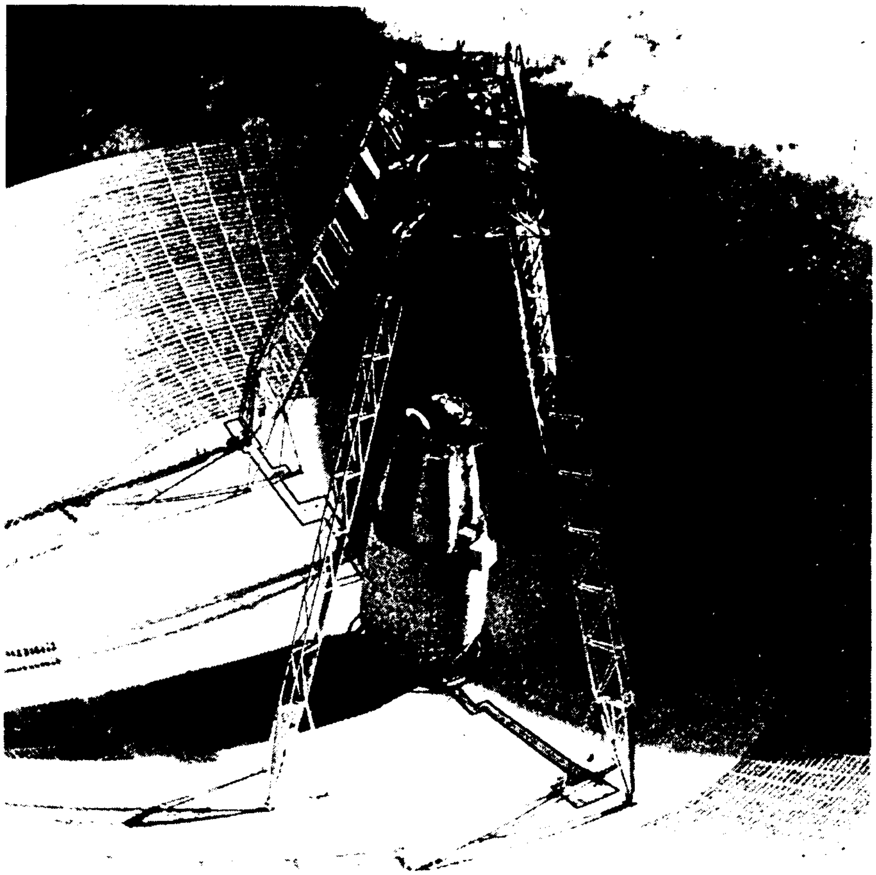

Figure 1. 70 meter Cassegrain Antenna at Goldstone

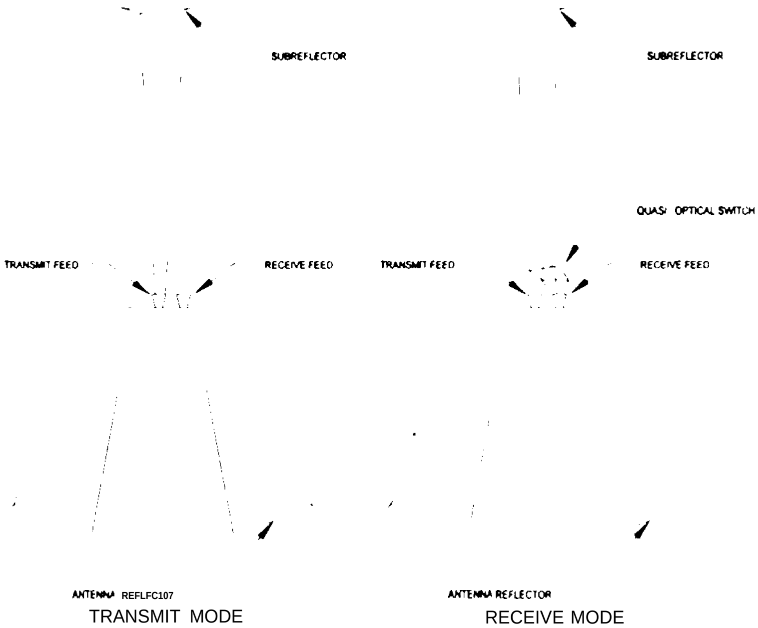

Figure 2. Quasi - Optical Transmit/ Receive Switch Schematic.

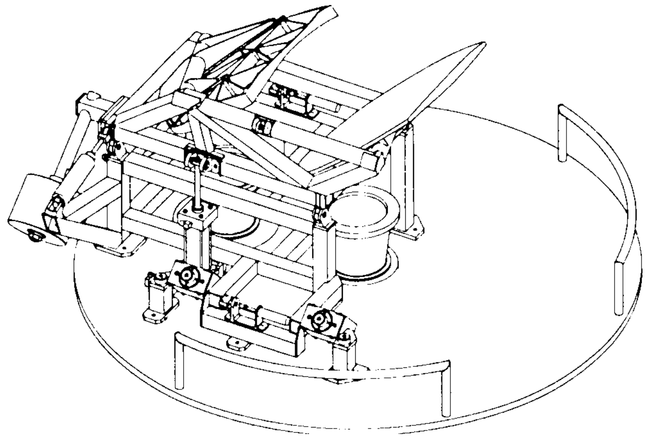

Figure 3. Quasi - Optical Transmit/ Receive Switch Mechanical Layout.

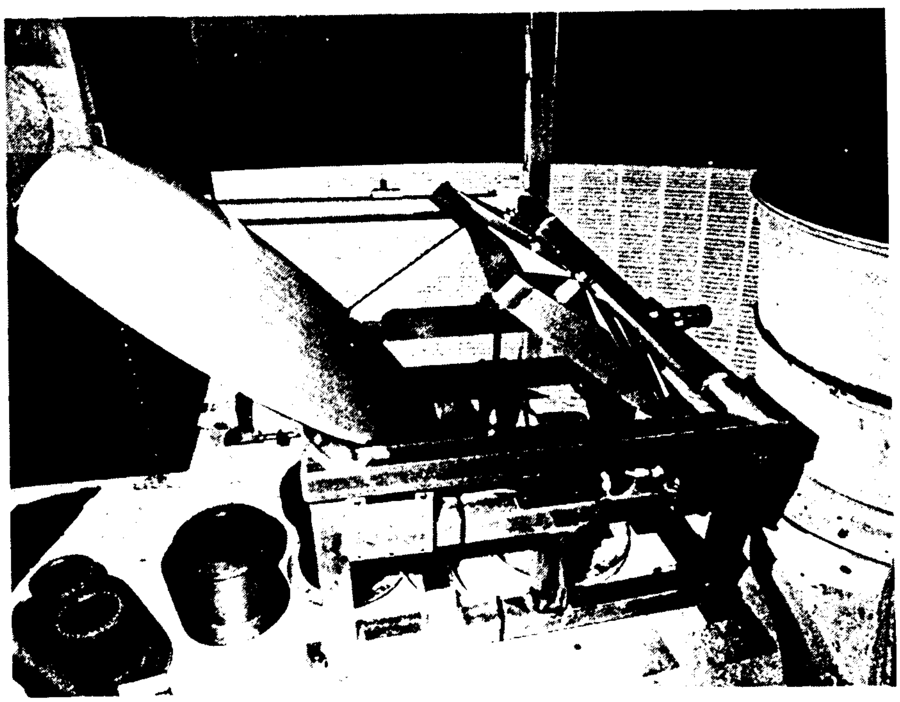

Figure 4. Quasi - Optical Transmit / Receive Switch Installed on Antenna