# AN INTEGRATED DQPSK DEMODULATOR FOR 14-GHZ SATELLITE COMMUNICATIONS APPLICATIONS*

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## ABSTRACT

An MIC assembly for direct DQPSK demodulation at 14 GHz is described. A time delay of 16.6 ns (120 Mbit/s) is achieved by edge-coupled bandpass filters. Quadrature phase detection is provided by a novel MIC topology that causes RF and IF ports to occur in adjacent pairs. An electronic phase shifter provides near linear phase shift with bias voltage. Temperature compensation maintains the phase errors to within 5° for a 20°C temperature change.

## Introduction

Future operational satellites will employ high-capacity satellite links using digital multiple access techniques (TDMA), which are in the experimental stage. A system with DQPSK on the up-link and CQPSK on the down-link offers considerable savings in system complexity; however, performance is slightly reduced compared to an all CQPSK system. This paper describes an MIC DQPSK demodulator which is considered sufficiently small, simple, and stable for space applications.

The circuits are tailored for use in the 14.0- to 14.5-GHz band at 120 Mbit/s. Demodulation is performed directly at 14 GHz, which eliminates the need for local oscillators. Noise figure and power levels are established by FET amplifiers preceding the demodulator. The organization of a regenerative transponder and demodulator is shown in Figure 1. The key component is the time delay element which must provide a stable 1-symbol delay (16.67 ns) and have a phase stability of ±3° over the operating temperature range. To date, the best results have been achieved with the configuration shown in Figure 2. The time delay filter, phase detector, and electronic phase shifter are realized in MIC form on fused silica.

## MIC Components

A bandpass MIC filter on fused silica was selected as the time delay element. Design techniques[1] are sufficiently advanced to easily achieve the required 16 ns of delay. A 10-pole filter with 4 ns of delay is shown in Figure 3 (dimensions: 2.0 x 0.350 x 0.015 inch). Figures 4 and 5 show transmission response and return loss for four of these filters in cascade, respectively. These results were achieved without tuning the filter.

The planar QPSK demodulator was constructed on fused silica with dimensions of 1.0 x 0.8 x 0.015 inch. The non-delayed signal is split by the Wilkinson hybrid and is crossed over the delayed signal by a cascade of interdigitated 3-dB couplers. The branch line coupler causes a near perfect 90° phase and power split of the delayed signal. Individual phase detectors are simple singly balanced mixers. The circuit is free of holes, "vias", or wrap arounds, and its back is a simple ground plane.

This circuit approach separates the delayed and non-delayed RF inputs and the detected P and Q bit streams into adjacent pairs in a single plane. The result greatly facilitates the integration of time delay filters, phase shifter, and phase detectors into a single 2-dimensional MIC assembly. Orthogonality of the P and Q channels is shown in Figure 6. The RF frequency was 14.2 GHz.

Phase shift as a function of reverse bias on the varactor is a nonlinear function. A photograph (Figure 7) shows an electronic phase shifter that partially linearizes phase shift vs bias voltage (Figure 8).

## Integrated Performance

Integrated performance was determined at 14.2 GHz with a 16.6-ns symbol time. Ultimately, the demodulator will be preceded by a channelizing filter with a bandwidth of approximately 80 MHz. The experiments were performed without the benefit of a channelizing filter, and the full spectrum was processed by the demodulator, thus providing a rather sensitive diagonistic for group delay distortion in the time delay filters as a result of temperature changes.

Uncompensated phase change versus temperature was determined to be approximately two electrical degrees per degree celsius. Also, most of this change, which was attributed to and dominated by the time delay filters, appeared to be virtually linear. A simple temperature control circuit was devised. Output voltage (for the varactor) was set at -0.75 V/°C, and offsets were set for 21°C to 41°C operation (beginning at -5 V on the varactor curve). The detected P and Q channels at 21°C are shown in Figure 9, and at 45°C in Figure 10. Phase error was maintained to less than five degrees electrical over the 21°C to 41°C range.

## Conclusions

It is believed that the simplicity and small size of the reported DQPSK demodulator could prove useful in a digital regenerative transponder for a digital satellite communications system.

## References

1. W. H. Childs, "Design Techniques for Bandpass Filters Using Edge-Coupled Microstrip Lines on Fused Silica," 1976 International Microwave Symposium Digest, pp. 194-196.

*This paper is based upon work performed in COMSAT Laboratories under the sponsorship of Communications Satellite Corporation.

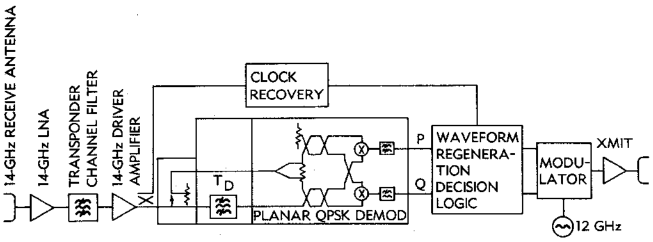


Figure 1. A Regenerative Transponder and DQPSK Demodulator

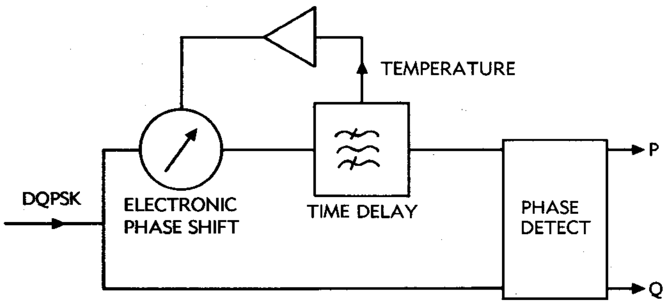


Figure 2. Block Diagram of the Temperature Compensated DQPSK Demodulator

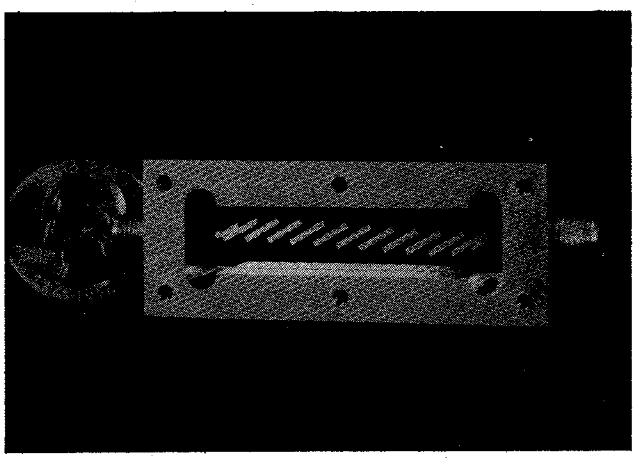

Figure 3. Time Delay Filter with 10 Poles and 4-ns Delay

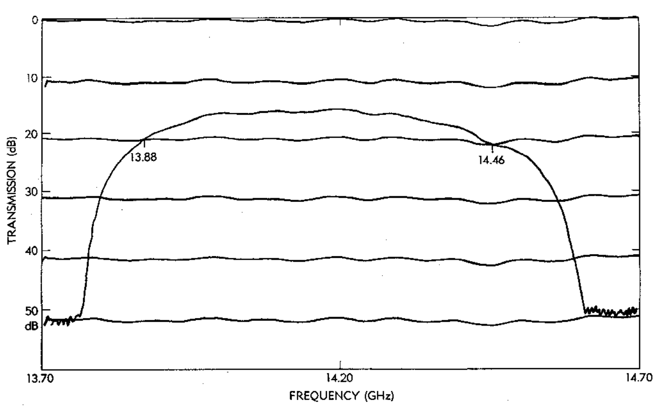


Figure 4. Transmission Response for 16-ns Delay Filter

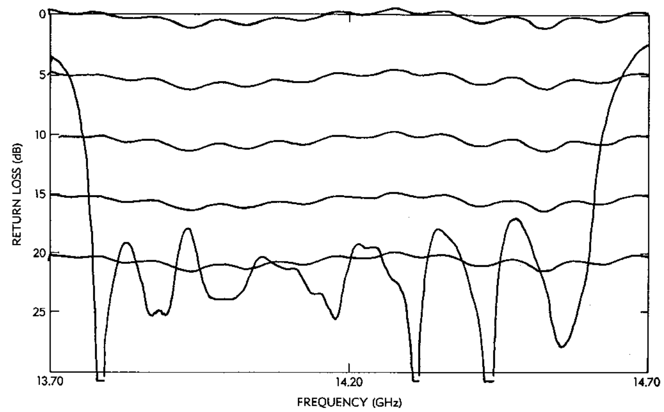


Figure 5. Return Loss for 16-ns Delay Filter

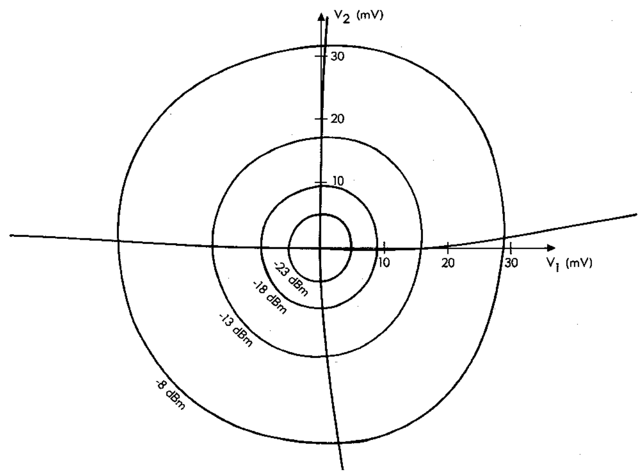


Figure 6. P and Q Channel Orthogonality

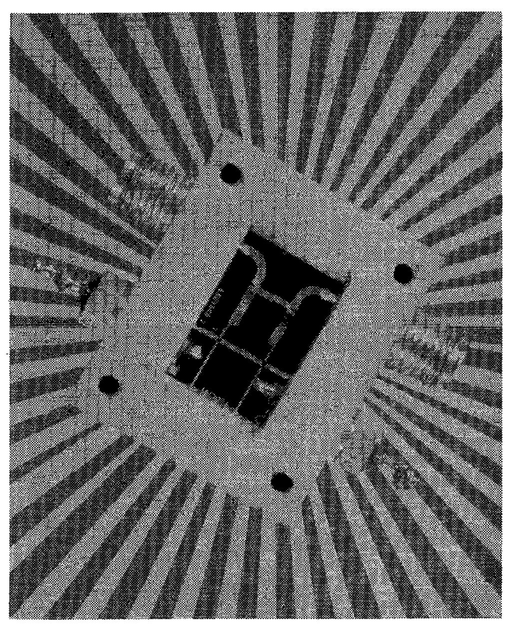

Figure 7. Electronic Phase Shifter

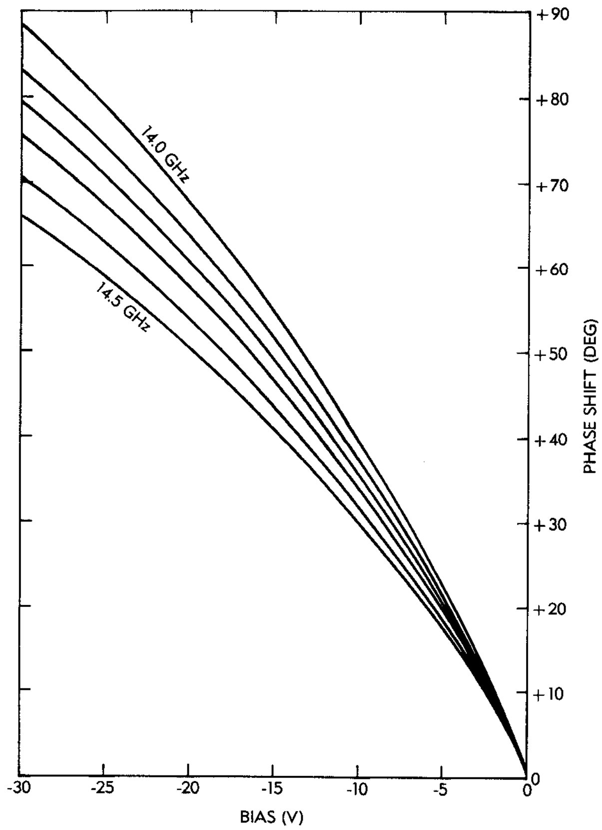


Figure 8. Phase Shift vs Bias Voltage

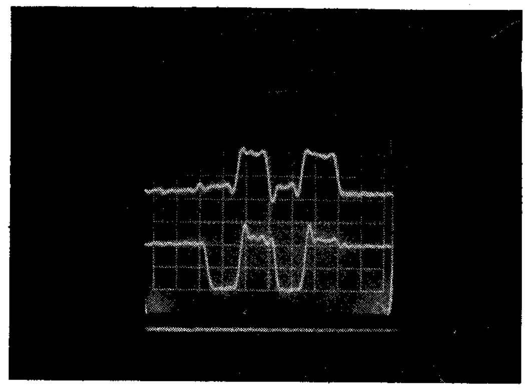

Figure 9. P and Q Channels at 21°C
(10 ns/division)

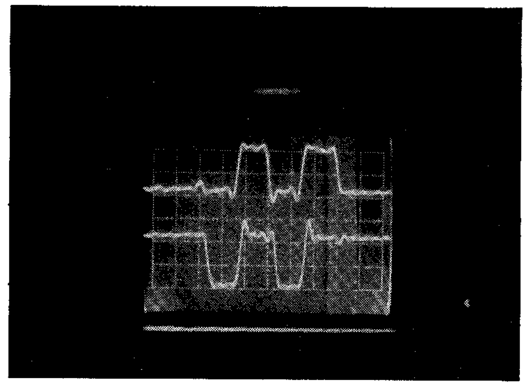

Figure 10. P and Q Channels at 45°C
(10 ns/division)