14 GHZ DIFFERENTIAL QPSK DEMODULATOR FOR REGENERATIVE SATELLITE REPEATER

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ABSTRACT

A lightweight 14 GHz, 120 Mbit/s differential QPSK demodulator for satellite application is described. The demodulator comprises a low-loss, temperature-stable waveguide delay filter and high-sensitive phase detectors. With this combination low-level operation and a high dynamic range are obtained.

Introduction

Future satellite communications systems will employ high-capacity digital transmission links using time-division multiple access techniques (TDMA), in some cases connected with satellite switching (SS-TDMA). In such complex systems on-board digital waveform regeneration would simplify the ground station equipment and reduce the power requirements in the up-link and the down-link. Due to the availability of the digital baseband signals aboard in an SS-TDMA system also the satellite hardware becomes simpler and more reliable.

The present paper describes a 14 GHz, 120 Mbit/s differential QPSK demodulator for possible use in the European Communications Satellite (ECS) System. The differential demodulation scheme (DQPSK) and its implementation directly at the RF have been chosen because this approach enheres the simplest, lightest and most reliable hardware /1/. In order to meet the design goals, which are high dynamic range and low input power, a demodulator has been developed differing in technology and performance from those described before /2/-/4/.

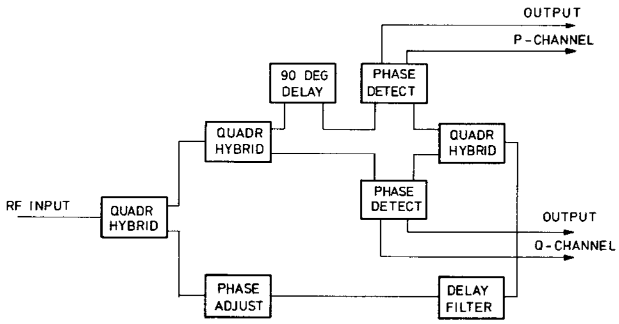

Fig. 1 Block diagram of differential QPSK demodulator

Demodulator Configuration

Fig. 1 shows a block diagram of the developed differential QPSK demodulator. The received signal is split by a quadrature hybrid and delayed in one path by one symbol period. The delayed and the non-delayed signals are then again split by quadrature hybrids and fed to phase detectors.

A 90° phase shift in one transmission line to the phase detectors produces the required orthogonality. If the phase adjuster is set so that the phase in the delayed path is an integer multiple of 2π the phase detectors provide the desired orthogonal baseband signals.

Demodulator Implementation and Performance

In order to achieve the design goals of high dynamic range and of low input level thorough investigations were required on the demodulator components. The investigations turned out that phase detectors have their optimum performance with equal level input signals. A high dynamic range cannot be obtained with a large level difference between the detector input signals. For that reason it is necessary to find a low-loss delay element. The most crucial requirement, however, is the thermal stability of the delay time.

Delay Element

At the given bit rate of 120.8 Mbps the delay element must provide a time delay of 16.6 ns. From system considerations the phase change of the delay element should not exceed ± 2° in the 10 to 40°C temperature range, which corresponds to a group delay stability of 0.8 x 10^{-6}/°C at 14 GHz.

Up to now such delay elements have been realized as transmission lines or bandpass filters in microstrip technique using various methods of temperature compensation /3/, /5/, /6/. All these solutions, however, suffer from the high insertion loss which is at least 16 dB in the 14 GHz band. A considerably lower insertion loss is obtained if the delay element is realized as a bandpass filter in waveguide technique. Using a material with low thermal expansion such as invar the phase variation can be kept within the accepted range.

The delay filter is shown in the photograph of Fig. 2, where it is mounted to the remaining demodulator circuitry. It is an 8th-order Chebyshev filter of 100 MHz bandwidth with one real pole for group delay equalization. The filter is folded and realised in a rectangular waveguide (WR62) of half height in order to reduce size and weight.

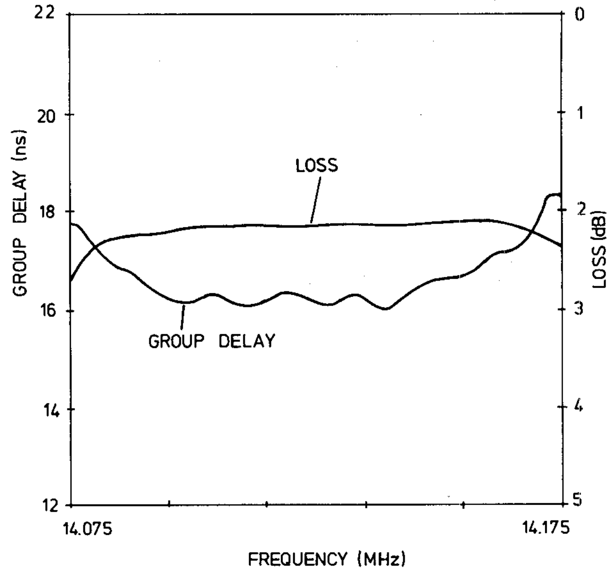

Fig. 3 Group delay and insertion loss of delay filter

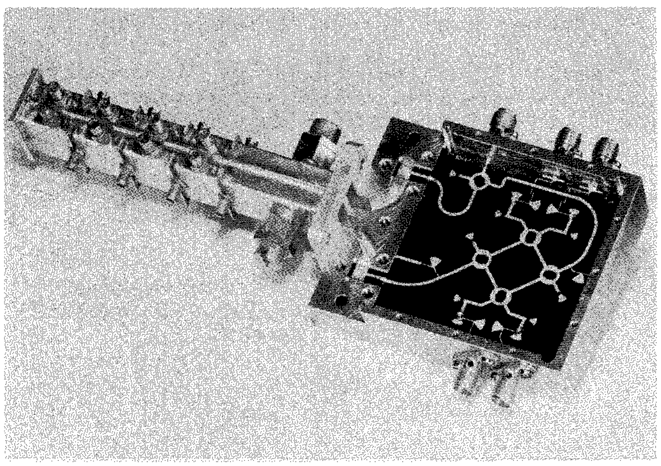

Fig. 2 Differential QPSK demodulator implementation

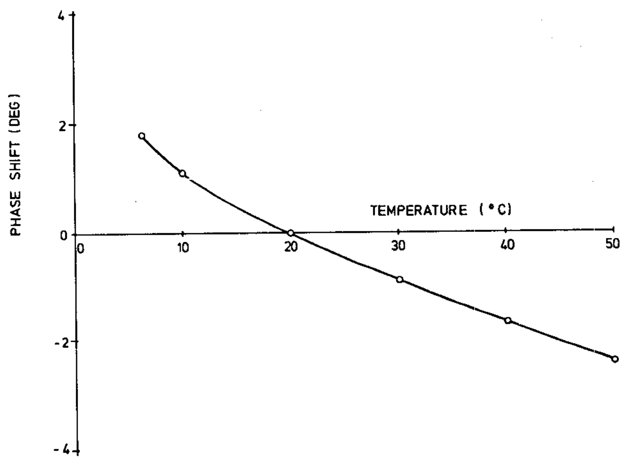

Fig. 4 Phase stability of delay filter

Fig. 3 shows the measured group delay and insertion loss of the delay filter. Both responses are sufficient flat as to cause almost no signal degradation. The insertion loss amounts to only 2.2 dB.

The transmission phase change versus temperature is shown in Fig. 4. Without any compensation technique the phase change remains below ± 2° in the 10 to 40°C temperature range. The phase stability could be further improved with special tuning screws working against the resonant frequency shift with temperature. However, for the present application the phase stability achieved is quite sufficient.

Phase adjuster

The phase adjuster in the delayed signal path must enable phase shifts of at least 180°. Because of the waveguide filter the coarse phase adjustment is easily accomplished by inserting spacers between the filter and the remaining circuit. The fine adjustment is carried out with quartz tuning screws at the filter ports (Fig. 2).

Besides the delay filter and the phase adjuster all components of the demodulator are realized in microstrip technique on a fused silica substrate (Fig. 2).

Phase detectors

The phase detectors are particularly designed for low-level operation and a high dynamic range /7/. They use zero-bias Schottky diodes in a special matching circuit. Fig. 5 shows the output characteristic of a separate phase detector for equal level input signals. Symmetrical curves with equidistant zero-crossings are obtained. The zero-crossings, whose spacing is crucial for the demodulator performance, show only small shifts during level and temperature variation. In the level range from -20 to +10 dBm the zero-crossing shift remains below 1° at room temperature and below 3° for temperatures between 10 and 40°C.

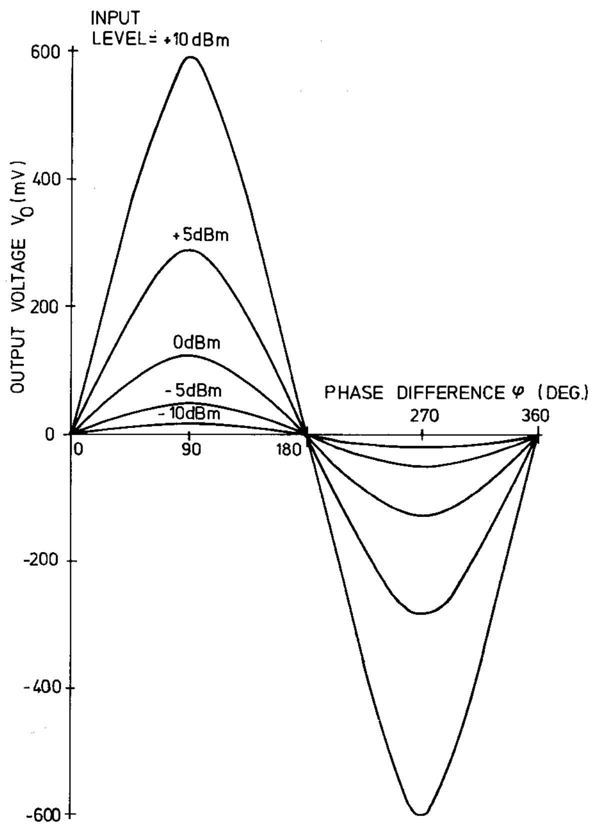

Fig.5 Output characteristic of phase detector at 14.125 GHz

The optimum operation level of the phase detectors is 0 dBm, corresponding to a demodulator input level of 5 dBm. At this input power, level variations of ± 10 dB cause only ± 2.5° phase change in the 10 to 40°C temperature range.

Conclusions

A lightweight 14 GHz, 120 Mbit/s differential QPSK demodulator for satellite applications has been developed which operates at input levels from -5 to +15 dBm. The low operation level and the high dynamic range are achieved by the combination of a low-loss delay element and specially designed phase detectors. The delay element, realized as a bandpass filter in waveguide technique, can also well compete with the microstrip approaches in size and weight.

References

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