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A Satellite Telemetry Transmitting System with Pre-Modulation Filtering

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The author describes the design of a space telemetry transmitter with special filtering techniques to reduce the potential for out-of-band interference

The total allotted bandwidth available for space-to-earth data transmission is 20 MHz in S-band, 375 MHz in X-band and 1500 MHz in Ka-band for Indian Remote Sensing (IRS) Satellites. The band allotted to communication satellites for space to earth communication in GEO missions is C-band (3.7-4.2 GHz). In this band, a small portion is identified for telemetry (TM) data transmission to ground. There is a need to transmit 1 Mbps payload data from a geostationary satellite using a C-band carrier. The interference between the regular TM data and the proposed payload data is reduced by adopting a premodulation filtering technique. The side lobe levels of the proposed system are low and a reduction in interference is expected.

Description of the System

The proposed data transmission system is for GSAT-4 satellite. It accepts data from the payload system, processes and modulates it on a C-band carrier. A QPSK modulator is used in this system. The modulated carrier is transmitted to the ground station after suitable amplification to meet the RF link margin.

The data transmission system consists of two identical transmitters operating at 4192.888MHz. One of the transmitters will be ON at a time, the other providing redundancy. It is possible to select any one transmitter by ground command. The carrier from the transmitter which is ON, is modulated by the data from the payload. The specifications of the transmitter are given in Table 1.

Carrier frequency:	4192.888 MHz
Frequency stability:	$\pm 2 \times 10^{-6}$
Modulation:	QPSK
Date rate:	1 Mbps
Data & clock interface:	RS 422

Table 1 · Specifications of the C-band data transmitter.

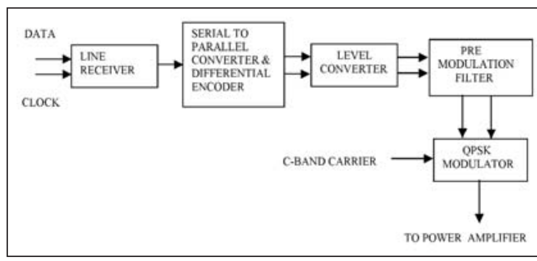

Figure 1 · Block diagram of C-band data transmission system.

Sharp transitions in Non-Return-Zero data in the time domain lead to a relatively wide PSD that rolls off quite slowly [1]. The first null occurs at a frequency equal to half data rate away from the carrier. It may be noted that 90% of the transmitted power of an unfiltered QPSK signal is within a bandwidth equal to the bit rate. The first and second side lobes of the QPSK spectrum are 13 dB and 18 dB down respectively from its value at the main lobe. Filtering can greatly reduce the side lobes levels. Here a pre-modulation filtering technique is chosen for the purpose. With this technique, interference with adjacent TM channels can be reduced.

The paper primarily focuses on the data processing system. The block diagram of the C-band data transmission system is shown in

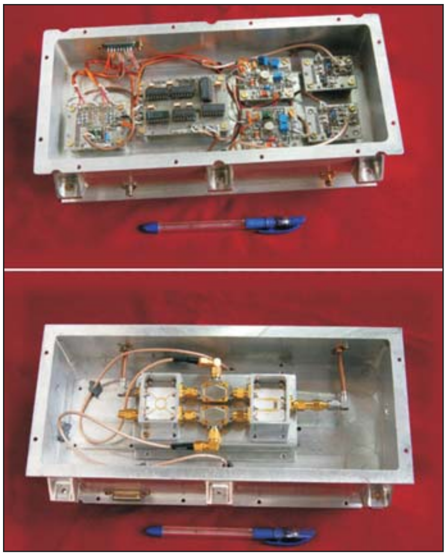

Figure 2 · Photographs of the data transmission system.

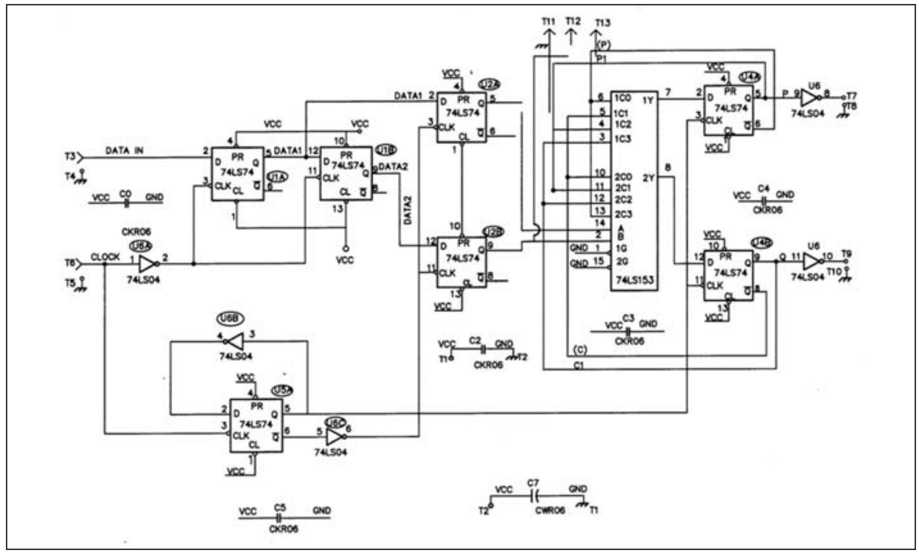

Figure 4 · Schematic of the serial to parallel converter and differential encoder circuit.

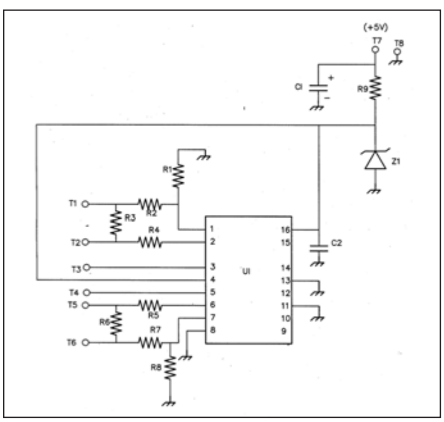

Figure 3 · Schematic of the line receiver circuit.

Figure 1 and its photograph in Figure 2. The data transmitter consists of two compartments connected back to back. A line receiver, serial to parallel converter, differential encoder, level converters and premodulation filters are housed in the top compartment. The bottom compartment consists of the QPSK modulator assembly. A brief description of each stage is given in the following sections.

Line Receiver

The clock and data signals are received from the payload using RS 422 interface. A line receiver (IC 26CLV32) converts the differential pair of signals received to TTL compatible levels. The schematic of the line receiver is shown in Figure 3. The design takes care of proper resistive network at the input to produce an adequate input differential voltage in the open line fault condition. The output of the line receiver is fed to a serial to parallel converter.

Serial to Parallel Converter and Differential Encoder

The serial to parallel converter circuit accepts the data at 1 Mbps along with clock and splits it into two parallel data streams (2×500 kbps), i.e., the I and Q data. The data is then differentially encoded. The schematic of the serial to parallel converter and differential encoder are shown in Figure 4. Data is passed through two D- flip-flops (54LS74) to get one and two bit delays in the data stream. The delayed data are synchronized with respect to half the input clock frequency to obtain two output data streams, the odd and even data bits at half the input data rate. The input and output waveforms of the serial to parallel converter are shown in Figure 5.

The circuit also consists of a differential encoder circuit, which is required to eliminate phase ambiguity during demodulation. There are eight different algorithms [2] for realizing the differential encoder for a QPSK modulator. The algorithm used in this system is given below.

A multiplexer IC (54LS153) is

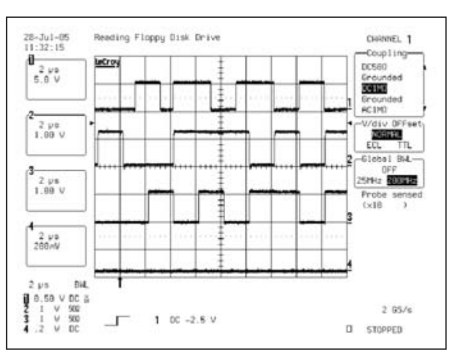

Figure 5 · Input and outputs of the serial to parallel converter.

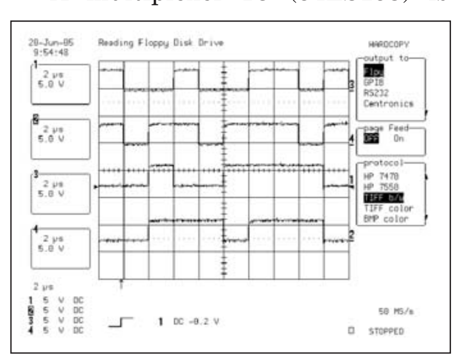

Figure 6 · Inputs and outputs of the differential encoder.

used to realize the differential encoder. Figure 6 shows the input and output waveforms of the differential encoder.

Level Converter

The differentially encoded data has TTL levels. This is converted to bipolar levels to provide suitable bias to the diodes in the modulator. The level converter circuit shown in Figure 7 is used for each data stream. Here, switching transistor 2N2905 is used. Different bias levels can be achieved by varying the potentiometers. Figure 8 shows the input and output waveforms.

Pre-Modulation Filter

In most wireless communication systems, the spectrum would be too wide to meet the Frequency Coordinate Committee (FCC) regulations and causes unwanted interference by spilling into adjacent channels. Placing a very narrow band pass filter at the output of the modulator could narrow the spectrum [3]. However, this is usually not practical since the quality factor (Q) of the filter must be very high, since the transmitted carrier frequency is much higher than the data rate. Such a high Q filter is difficult to realize, expensive and can cause significant distortion on the transmitted signal due to large phase variations at the band edges. A better technique to limit the output spectrum is to filter the base band I and Q signals before they are applied to the modulator.

Many authors have tried various pulse shaping methods [4, 5, 6]. Here, we propose a new five-element filter for base band pulse shaping. The filters are designed at 350 kHz. The outputs of the level converters of the previous stage are fed to these pre-modulation filters. The schematic of the filter is shown in Figure 9 and its frequency response in Figure 10. The random data applied at the filter input and the resultant output are shown in Figure 11.

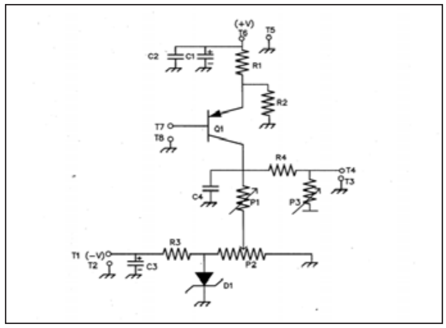

Figure 7 · Schematic diagram of the level converter.

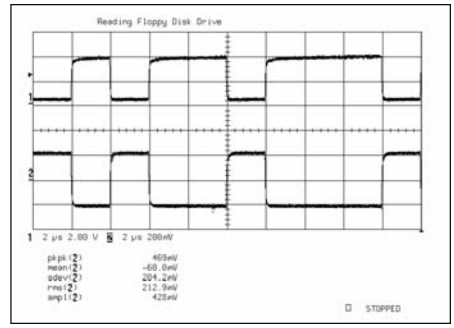

Figure 8 · Input and output of the level converter.

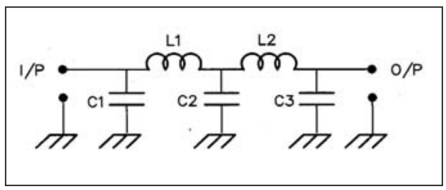

Figure 9 · Schematic of the pre-modulation filter.

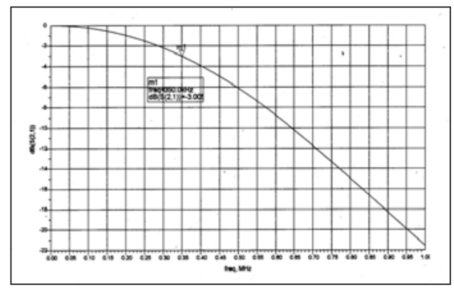

Figure 10 · Response of the pre-modulation filter.

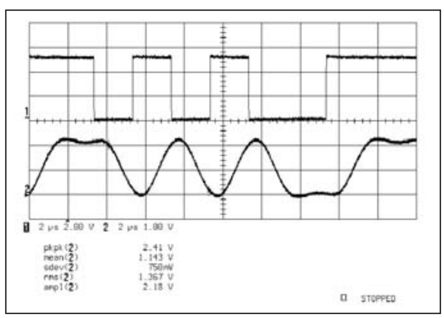

Figure 11 · Input and output of the premodulation filter.

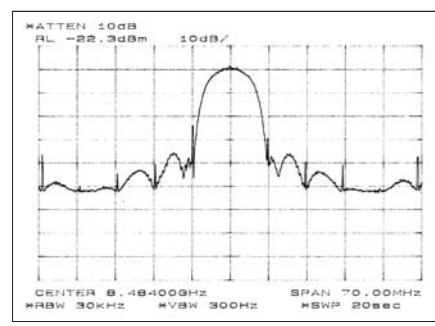

Figure 12 · QPSK modulated spectrum with pre-modulation filtering.

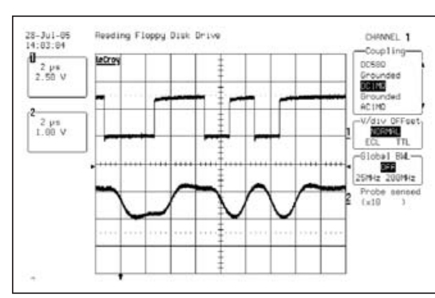

Figure 13 · Encoded input to modulator & output of demodulator.

QPSK Modulator

The QPSK modulator is realized using a 3 dB, 90° hybrid, two double balanced mixers and a power combiner [7]. The 3 dB/90º hybrid coupler and Wilkinson power combiner were designed at C-band on alumina substrate. A QPSK signal is generated by the linear addition of two BPSK signals in quadrature.

The RF carrier at 4192.888 MHz is fed to the QPSK modulator. The 3-dB hybrid produces quadrature carriers for the I and Q channels. These are fed to double balanced mixers. The I and Q data outputs of the pre-modulation filters are fed to the mixers and modulate onto the carriers. The outputs of these mixers are combined using in-phase Wilkinsons power combiner to give a QPSK modulated output. With this configuration, a QPSK spectrum with very low side lobe levels is achieved. From Figure 12, it can seen that the first and second side lobes are 35 dB and 43 dB down, respectively, compared to main lobe. Thus, premodulation filtering technique is useful for reducing the side lobe levels. With the low side lobe levels, interference with other TM channels is reduced.

Demodulator

In order to evaluate the data quality, the modulated carrier at 4192.888 MHz was down converted to 70 MHz. and fed to a demodulator. The demodulated output consists of recovered two data streams. Figure 13 shows one of the differentially encoded inputs to the modulator and the output of the demodulator. It can be seen that the demodulated data is identical to the input data except for the pulse shaping and a small time delay due to signal path difference.

Conclusion

The new QPSK data transmission system at C-band was developed to transmit data from space to ground. Premodulation filtering technique was used here to reduce the bandwidth of the spectrum. A simple filter at the input provided the desired effect. The reduction in the side lobe levels of the QPSK spectrum is very important to reduce unwanted interference caused by spilling of signals into adjacent channels. The concept can be applied to remote sensing satellites also where adjacent channel interference is important.

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