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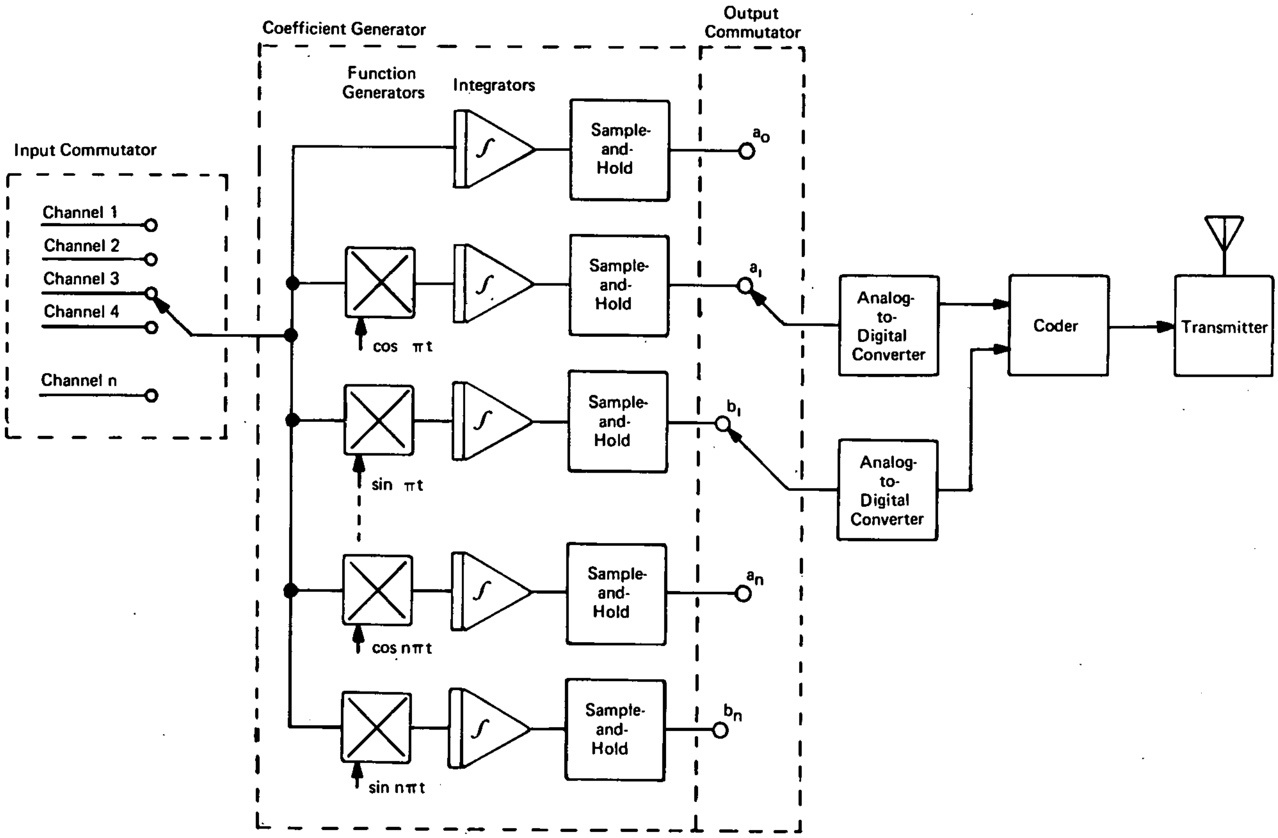
High Efficiency Telemetry Method

The efficiency and accuracy of data transmission can be markedly enhanced by a method that was originated for use in space exploration. It is applicable to recording industrial process data and sampling magnetically recorded analog signals in data compression, as well as to digital television systems, and other systems where some of the functions vary more rapidly than others. Previous methods were not able to handle input signals with a frequency of 2 Hz or greater, because of the number of inputs required and the transmission bit rate limitations of the equipment.



In the new method, the waveform is mathematically analyzed into its component waves by a Fourier series approximation of the commutated input signals. This technique represents the information signal more accurately than previous methods, and requires fewer information bits. Both the analog and

(continued overleaf)

digital mechanizations are relatively simple. They contain new combinations of well known circuits that generate the coefficients of the Fourier series terms in accordance with the harmonic content of the waveform to be transmitted.

The existing sample-and-hold system (i.e., a simple electronic switch commutation) is equivalent to converting the Fourier coefficient a_0, which is for the first (or direct current) term of the series. This coefficient gives the average value of the input signal during the commutated interval. Hence, for the case of "slow" input, the new method provides no advantage.

For an input signal that contains a harmonic of 2 Hz or more, additional coefficients are needed to represent the commutated signal adequately.

In order to determine the successive coefficients of a trigonometric series to represent any empirical period wave, circuits that compute the functions, f(t), are needed, where

$$a_n = \int_{-T/2}^{T/2} f(t)\cos\omega_n t\,dt \qquad n = 0,1,2,3,\ldots,N$$

and

$$b_n = \int_{-T/2}^{T/2} f(t)\sin\omega_n t\,dt \qquad n = 1,2,3,\ldots,N$$

In the above, T is the sample interval, t is time, and $\omega_n = \frac{2\pi n}{T}$

The approximation for f(t), s(t) is:

$$f(t) \approx s(t) = a_0 + \sum_{i=1}^{n} a_i\cos(i\pi t) + \sum_{i=1}^{n} b_i\sin(i\pi t)$$

As shown in the diagram, the sampling time is set by the input commutator which is driven at a constant rate. The analog output of each channel is simultaneously analyzed for harmonic content by the coefficient generator. The a_0 component is derived from straight integration over the integration time (within the sampling time) by the integrator and the sample-and-hold circuit. The output of this circuit is commutated synchronously with the input by the output commutator. This a_0 output level is converted to a binary number in an analog-to-digital converter, encoded, and transmitted. The a_1 to a_n coefficients are derived by being multiplied with the $\cos\pi t$ and the $\sin\pi t$ signals before being integrated over the sampling time by circuits identical to the a_0 integrator and the sample-and-hold circuit. The sine and cosine outputs are sequentially commutated, converted, encoded, and transmitted in the same manner as the a_0 coefficient.

In a digital implementation of the Fourier coefficient generator, the commutator functions as described above. The output signal is analyzed by the Fourier coefficient generator. All of the coefficients are generated simultaneously upon the start of each commutated channel, and are shifted out sequentially to be encoded and transmitted, as in the analog implementation.

The digital coefficient generator employs a voltage-to-frequency converter to translate the a_0 level directly to a count accumulated over the integration period. The integration period is controlled by an AND gate, and the count representing the coefficient is accumulated in an up-down counter. This coefficient is then stored in a shift register.

The a_1, b_1 to a_n, b_n coefficients are generated by multiplying with the corresponding $\cos n\pi t$ and $\sin n\pi t$ signals in the analog multipliers, the outputs of which change the frequency of their respective voltage-to-frequency converters. The integration period and count accumulation are as described for the a_0 coefficient. The coefficients are all stored in a shift register and are shifted out serially to the coder and transmitter for transmission to the base station where, by means of a digital computer, the coefficients are summed to obtain the characteristics of the original signal.

Note:

Requests for further information may be directed to:

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Reference: TSP71-10371

Patent status:

This invention has been patented by NASA (U.S. Patent No. 3,548,107), and royalty-free license rights will be granted for its commercial development. Inquiries about obtaining a license should be addressed to:

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