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NASA TECH BRIEF

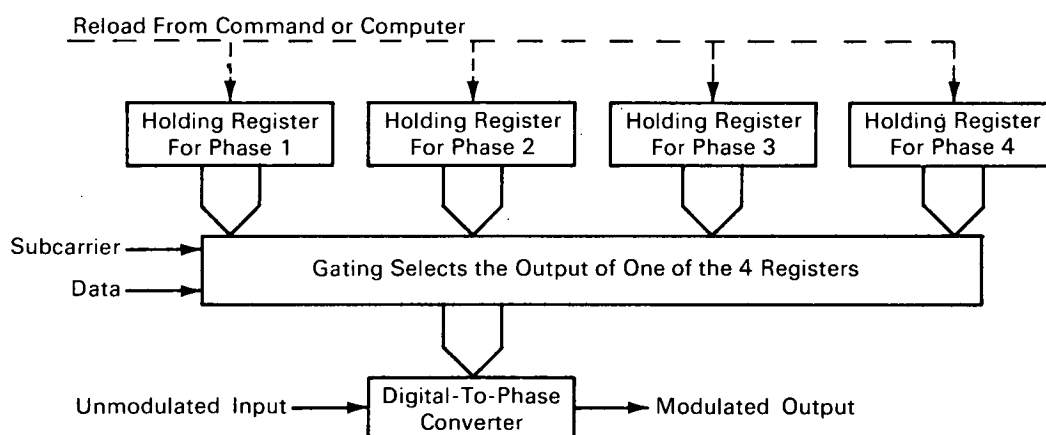## Digital Phase-Modulation/Multiplex System

Figure 1. Programmable Modulator System

This innovation represents an advance in the art of telemetry data modulation/multiplexing, with applications to terrestrial data communications systems. Uses in computer installations and other data links using a single channel are also feasible.

The uniqueness of this system lies in the concepts of combining and modulating subcarriers and pulse code modulation (PCM) data entirely with digital logic, and of phase modulating an rf carrier with a digital representation of the composite subcarrier signal. The advantages in this approach are that (1) the replacement of analog circuits by digital logic results in greater reliability and cost savings; (2) the interface between the data handling system and the rf system is made all-digital; and (3) the modulation indices or power allocations to various subcarriers are made programmable, and therefore more flexible.

Planetary spacecraft have used subcarrier frequency multiplex to separate independent PCM data streams, transmitting engineering telemetry at a low rate on one subcarrier and science data at a higher rate on another. The two subcarriers were added in a linear summer in a ratio appropriate to the desired modulation indices and applied to a carrier phase modulator. Turnaround ranging modulation was added in the phase modulator.

This new system permits programmed control of the modulation indices and, consequently, the modification of these indices when required. Another advantage of the new technique is the reliability of its digital circuitry.

The technique currently in use for subcarrier modulation is to have each of several PCM data streams phase-shift keyed modulating a subcarrier. The subcarriers are then added in ratios appropriate to the desired allocation of power between subcarriers, and between subcarriers and carrier. The subcarrier modulators and the summing amplifier are implemented

(continued overleaf)

with linear circuitry. Provision is usually made for the selection of alternate "modes" or weights in the weighted summation.

Under most conditions, the use of square-wave signals for subcarriers results in lower intermodulation losses in a phase-modulated carrier system than does the use of sinusoidal subcarriers. Because the square waves are also easy to generate and manipulate, square-wave subcarriers are usually used.

The essence of the new concept (see Fig. 1) is that the discrete carrier phases can be regarded as boolean functions of the data, subcarrier and mode control signals treated as binary variables. Thus, if one constructs a digital carrier phase modulator (digital-to-phase converter, D/PC), the subcarrier modulators and summing amplifier are replaced by code conversion logic which maps the binary data, subcarriers, and control into a binary representation of phase. Figure 2 shows the data stream D_A, D_B, . . ., the subcarriers S_A, S_B, . . . , and the mode controls C_1, C_2 being transformed in "code conversion" logic to a set of phase bits which control a D/PC.

The design of the code conversion logic can be accomplished in two ways. One way is to use a pair of diode matrices—an encode matrix followed by a decode matrix—to convert the parallel k-bit number representing the data, subcarrier, and control variables into an m-bit number representing the desired carrier phase. A less tedious and more flexible method is to use a set of holding registers in which the possible carrier phase numbers are stored, transferring the appropriate register state in parallel to the D/PC through gating controlled by the data and subcarrier variables. The in-flight programmability of this system is apparent—the holding registers are loaded, via the command system or the spacecraft computer, with the desired phase angles.
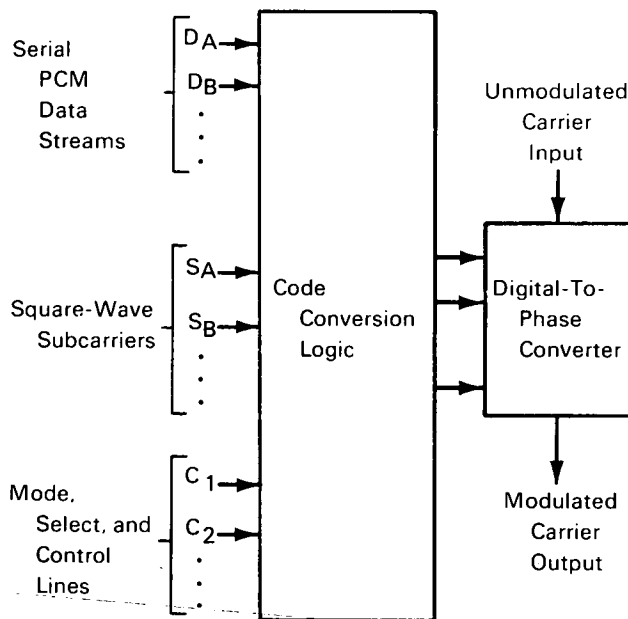
Patent status:

Figure 2. Digital Phase Modulation