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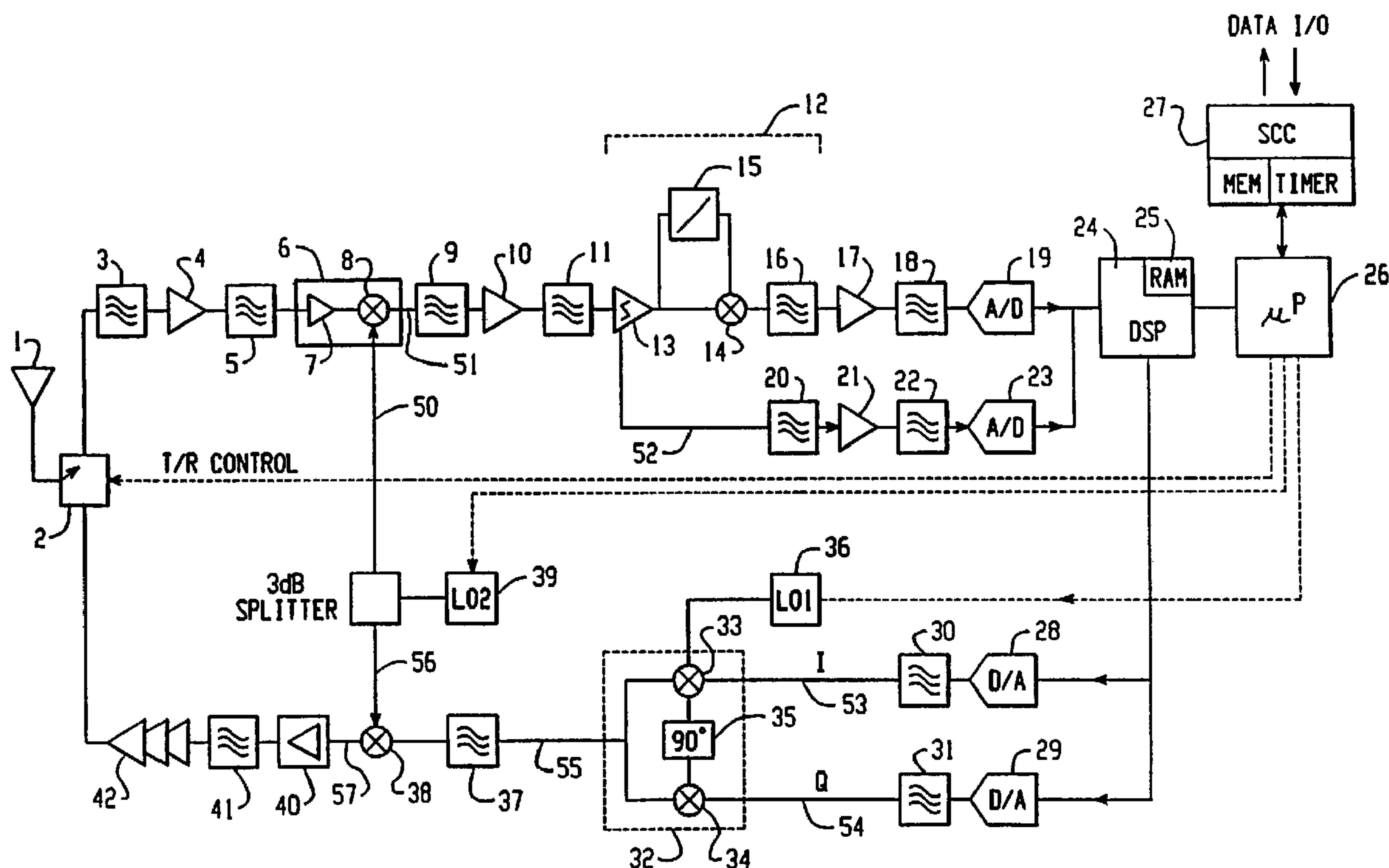
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(54) Title: WIRELESS RADIO MODEM WITH MINIMAL INTERDEVICE RF INTERFERENCE



(57) Abrégé/Abstract:

A wireless radio modem that may be incorporated into a host system or connected through a PCMCIA or similar port to a host system includes radio frequency modulation/demodulation circuitry employing electronic device elements that operate in a frequency range that minimizes the RF interference between the radio modem and the host system. Radio modem power conservation is maximized by 1) simplifying signal modulation processing by use of a two-point waveform transition table, thereby reducing processing requirements; and 2) incorporating a "sleep mode" feature in which all non-timer circuitry is powered-down when not in use.

ABSTRACT

A wireless radio modem that may be incorporated into a host system or connected through a PCMCIA or similar port to a host system includes radio

5 frequency modulation/demodulation circuitry employing electronic device elements that operate in a frequency range that minimizes the RF interference between the radio modem and the host system. Radio modem power conservation is maximized by 1)

10 simplifying signal modulation processing by use of a two-point waveform transition table, thereby reducing processing requirements; and

2) incorporating a "sleep mode" feature in which all non-timer circuitry is powered-down when not in use.

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WIRELESS RADIO MODEM WITH MINIMAL
INTERDEVICE RF INTERFERENCE

5 TECHNICAL FIELD OF THE INVENTION

 This invention relates generally to data communication at radio frequencies in a wireless environment and, in particular, to a method of wireless data communication and to a device that can
10 be imbedded within a host data processing or communications unit (such as a PC, a laptop, a workstation, a personal digital assistant (PDA), a two-way pager or other equipment for data communications or processing) or attached directly
15 through an external data interface, such as one that is constructed and controlled in a manner that meets the standards set forth in two documents entitled "PC Card Standard," Release 2.0, and "Socket Services Interface Specification," Release 1.01,
20 both published by the Personal Computer Memory Card International Association (PCMCIA), in September 1991. As will be appreciated by reference to the specification that follows, although communication through a PCMCIA interface is preferable, the
25 invention is not restricted to a particular communication interface and may be connected in any manner to a host data processing or communications unit (either, a "host unit"), or integrated into such a unit. The method and device enables a host
30 unit to transmit data to and receive data from a communication network wirelessly so that the RF interference between the host unit and the radio modem is minimized and power consumption is at a reduced level. It is envisioned that in its
35 preferred use, the invention will be used to

communicate between a host unit and a remote data processing or communications device, either directly or via a network through a data transmission/reception network station.

Wireless radio modems are used to permit remotely located computers and
5 other data communications equipment to communicate with one or more other computers or equipment for data communications, usually as part of a computer network. Over the past several years, a number of efforts have been undertaken to reduce the size, weight, power consumption and portability of radio modems in order to increase their attractiveness to both the technical community and the consuming public.
10 In spite of advances in technology, most state of the art radio modem designs usually involve a flexible cable connection to the host unit and a bulky external battery pack to supply the necessary power. Previous attempts to incorporate a radio modem within a host unit or to connect a radio modem through a PCMCIA interface have resulted in extremely poor operating performance predominantly as a result of radio frequency
15 interference caused by electrical noise generated by the host unit.

The present invention has utility in allowing a host unit to communicate with a wireless network. The present invention is a wireless radio modem for transferring data between a host data processing device and a remote data processing device or a data transmission/reception network station comprising transmission/reception means for
20 transferring data at radio frequencies between the host data processing device and at least one of the remote data processing device and the data transmission/reception network station and modulation/demodulation means wherein the modulation/demodulation means comprises means for demodulating data received from the transmission/reception means and means for modulating data generated by the
25 host data processing device, wherein the means for demodulating data includes frequency discrimination means having one or more electronically-coupled piezoelectric phase-shift devices and the means for modulating data includes a digital signal processor with a waveform transition look-up table stored in a storage area and generated using single sideband suppressed carrier modulation and an orthogonal
30 component mixer circuit operationally connected to the digital signal processor to create a modulated output data signal. The modem may be designed to be located within a host unit, or connected to a host unit through an

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external port, such as a PCMCIA interface, so that the host unit can communicate with other units for data processing or communication via a wireless data network. In its preferred embodiment, the radio
5 modem is designed to operate in a wireless data network that uses packet-switched communication such as a network that uses the Mobitex™ network protocol, the Ardis™ network protocol or the Cellular Digital Packet Data (CDPD) wireless network
10 protocol. The radio modem design allows different network protocols to be supported by software changes only (i.e., with no substantive hardware modifications), so the scope of the invention is not limited to any specific protocol. For the preferred
15 embodiments, however, reference is made to the Mobitex™ standard, which is a published communications standard for the Mobitex™ wireless network. The references herein to the standard shall mean the Mobitex Interface Specification, Rev.
20 3A, published September 1994 and available from RAM Mobile Data, 10 Woodbridge Center Drive, Woodbridge, NJ 07095.

The radio modem is preferably designed to be built into a host unit (the OEM version) or to be
25 directly connected to a host unit through a PCMCIA interface (the PCMCIA version), although the design may be incorporated into a stand-alone modem separate from the host unit. Both the size and performance of the present invention represent a
30 significant improvement over the state of the art.

The radio modem hardware and software of both the OEM version and the PCMCIA version are carefully designed to minimize power consumption.

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In the preferred embodiments, each version can be configured in one of two forms: (i) with an on-board microprocessor that provides overall control of the operation of the various subsystems of the radio modem (the "on-board processor form") or (ii) without an on-board processor, whereby the essential control functions that are performed by the microprocessor in the on-board processor form are performed by the host unit microprocessor (the "microprocessor-less form"). To reduce power consumption significantly in each version, the key power-consuming components are placed into lower power modes when they are not needed and are placed in a higher power mode only when data that the radio modem is to process are detected or when a predetermined period time has elapsed from the point the components have been put into a lower power or a "sleep" mode. As one of ordinary skill in the art of digital communications equipment design will appreciate, the microprocessor is one of the key power-consuming components in the on-board processor form. In addition to the power management circuitry, the method of operation of each version of the radio modem was optimized to reduce power consumption using low-power components and power-efficient design where possible.

Operational performance is also enhanced over the state of the art because both versions of the radio modem are designed to operate in the high electrical noise environment present within, or immediately proximate to, a host unit. The major electrical noise immunity strategy employed is the use of circuitry designed to operate outside the

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electrically noisy frequency bands that are present within an operating data processing unit. Among the features that enable the modem to avoid the RF interference of its host data processing unit is the
5 implementation of frequency discrimination at an intermediate frequency (at or above 10.7 MHz) that is well above the noise frequencies emanating from the operation of a host unit.

In order to generate the intermediate
10 frequency at which discrimination takes place, the receiver circuitry uses a single intermediate frequency down conversion step. In the preferred embodiment, the intermediate frequency is 45 MHz. After down conversion the signal is channel filtered
15 and then demodulated and digitized. The resulting digitized signal is then conveyed to a digital signal processor ("DSP") where the data is recovered and conveyed to the host unit.

On the transmission side, the transmitter
20 circuitry accepts data from the host unit, via the DSP, in a pre-modulated form. In the preferred embodiment, the data received by the transmitter is modulated using either quadrature modulation or baseband modulation, although one of ordinary skill
25 in the art will appreciate that various modulation techniques could be applied to modulate the signal received from the DSP.

Quadrature Modulation

30 In the implementation in which the data are quadrature modulated, the DSP presents the signal to the modulation circuitry in in-phase and quadrature phase components. The signal is then

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modulated directly, using quadrature modulation, and is filtered, amplified, upconverted, filtered and then amplified again before being conveyed, via a transmit/receive switch, to an antenna for
5 propagation.

Baseband Modulation

In the implementation in which the data is baseband modulated, the DSP presents the signal to
10 the modulation circuitry in the form of two modulation voltage signals for the Voltage Controlled Temperature Compensated Crystal Oscillator (VCTCXO) and Voltage Controlled Oscillator (VCO). The signal is then frequency
15 modulated, using baseband modulation and is filtered and then amplified before being conveyed, via a transmit/receive switch, to an antenna for propagation.

20 *Modulation Lookup Tables*

The modulation scheme, in the preferred embodiment, relies upon pre-calculated wave segments that are pieced together at run time to produce smooth Gaussian Minimum Shift Keyed (GMSK) or GMSK
25 Inphase (I) and Quadrature Phase (Q) modulated waveforms. For efficiency purposes and to reduce the processing time required to modulate the signal (and thus the processing power required), a look-up table stored preferably in DSP memory is employed as
30 a part of the modulation process.

In the case of quadrature modulation, the look-up table provides precalculated waveform segments that are pieced together, taking into

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account the interrelationship of a digital four bit transmission stream on the waveform shape associated with the second bit of the four bit stream. Simple transforms are used to phase shift this signal by
5 steps of 90 degrees, to compensate for the different phases that the I and Q channels may be in at the start of the segment.

In the case of baseband modulation, instead of using the I and Q channels, baseband
10 signals are encoded. Thus, it is only necessary to have one channel instead of two, as both channels are either the same, or related by a constant multiple. The need to shift the signal by 90 degrees is no longer necessary in baseband, as there
15 is no need to use accumulated phase from previous bits.

The modulation tables, in the preferred embodiment, were generated by a program called MODTAB. MODTAB.C, the main c source file found in
20 Appendix A, contains the mathematics to generate the modulation tables. The formulas in this code implement the modulation scheme in a simplified form and the source code is structured in such a manner that certain of its modules can be used to generate
25 tables for quadrature phase modulation and not used when baseband modulation tables are desired.

For both types of modulation, the GMSK wave form is first calculated and used to generate a baseband modulated wave form. To FM modulate the
30 baseband GMSK signal into I and Q signals for quadrature phase modulation, a phase accumulator is used. Because frequency is a rate of phase change, the baseband values from the GMSK wave form

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represent the rate of change of the phase accumulator. The Sine and COSINE of value in the phase accumulator is then used to calculate the I and Q signals. Optionally, the effect of an RC
5 filter on the I and Q signals can be compensated for by applying the inverse function of an RC filter to the I and Q signals. Thus, the output of the RC filter can be forced to correspond with the desired wave form. The math is performed in a laborious
10 manner, using floating point evaluation. For each possible combination of four bits, all the shapes for all four bits are generated. To build the tables, the interval between the centers of bits 2 and 3 is then bracketed, extracted and placed in the
15 table.

When generating tables for baseband code, the phase accumulator and SINE/COSINE calculation steps are skipped, and the baseband wave forms are placed in the tables directly. There is also no
20 need to compensate for RC filter effects in the development of the baseband table. When the tables are generated and stored, modulation can be accomplished through application of the table data.

25 The object of the demodulation scheme is to provide a nearly optimal method for decoding bits accurately, while using as little processing power and additional hardware as possible, in order to keep power consumption and cost to a minimum. In
30 order to eliminate the need for sophisticated hardware filters, the incoming signal is sampled at a rate that is a multiple of the bit rate. In the preferred embodiment, the sampling rate is six times

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the GMSK bit rate. A Finite Impulse Response (FIR) filter is applied to the signal every n samples, where n is the number of analog to digital converter (A/D) samples per GMSK bit. This implements a
5 decimating filter, producing output samples at a rate equal to the bit rate. The FIR filter cuts off sharply after a frequency equal to half the bit rate, thus keeping to a minimum the amount of aliasing resulting from the decimation. This
10 technique takes advantage of the Nyquist sampling theorem, fully capturing a bandwidth of half the sampling rate by taking periodic samples.

Even though the effective sampling rate is equal to the bit rate, repetitious patterns of
15 seemingly lower bit rates, such as a GMSK Bitsync of the pattern 110011001100, can nevertheless be recognized, as such a pattern produces a wave form similar to a sinusoid at a frequency of one fourth the bit rate. A series of increasingly stringent
20 criteria is used to determine whether the received signal is a bit sync pattern. When all the criteria are satisfied, preferably 12 samples of the bit sync are correlated to SINE and COSINE functions.

Because 12 samples represent three complete periods
25 of the sinusoid, compensating for different direct current (DC) levels is not necessary. Because the SINE and COSINE functions need only be evaluated at 90 degree intervals, this process is trivial. The SINE function, for example, takes on values of
30 0,1,0,-1,0,1,0,-1,0 . . . etc..

The two resulting correlations of the SINE and COSINE functions are then combined to form a Cartesian vector and mathematically transformed

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through rotations of 90 degrees to be within an angle of ± 45 degrees. A cubic function of the slope of this vector is then used to approximate the arctangent of the resultant vector. The difference
5 between the resultant angle and 45 degrees (or - 45 degrees, whichever is closer), divided by 90 degrees is the fraction of a bit by which the sampling point in the decimation filter must be adjusted to be coincident with the center of the GMSK bit. In the
10 preferred embodiment, for ease of implementation, the adjustment is rounded to the nearest A/D sample. As one of ordinary skill in the art will appreciate, however, enhanced accuracy can be obtained by varying the shape of the FIR filter to accomplish
15 shifts of less than one A/D sample. When the adjustment is performed, samples coincide with the centers of bits, so bit decoding can be done using a threshold that is a function of a DC level calculated from the 12 samples used for bit
20 synchronization, as well as the value of the previous bit.

OBJECTS OF THE INVENTION

Accordingly, it is an object of the
25 invention to provide a radio modem with modulation/demodulation means that incorporates circuit elements that operate at frequencies outside the frequency range of the RF noise associated with the host unit in which the radio modem is installed.

30 It is another object of the invention to provide a radio modem in which frequency discrimination occurs at a data discrimination frequency of 10.7 MHz or higher.

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It is a further object of the invention to perform FM frequency discrimination through the use of one or more piezoelectric phase-shift devices, such as surface acoustic wave ("SAW") filters, surface transverse wave ("STW") filters, surface skimming bulk wave ("SSBW") filters, leaky SAW filters or crystal filters such that the frequency discrimination takes place outside the RF noise frequencies generated by the host unit associated with the radio modem.

It is a yet further object of the invention to provide a stored waveform transition table as part of the digital signal processing circuitry to minimize processing time and power consumption during the digital signal processing phase of the operation of the radio modem.

It is another object of the invention to provide circuitry for minimizing power consumption in a radio modem that permits the major power-consuming components of the radio modem to enter into an inactive or lower-powered state and to be later activated or repowered by the detection of data communications or by the expiration of a predetermined period of time, whichever occurs first.

These objects as well as others appreciated by those of ordinary skill in the art will become apparent from the detailed description and in reference to the drawings that follow. The specific examples that are set forth in the detailed description of the preferred embodiment should be understood to be given for illustrative purposes

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only and are not intended to limit the spirit and scope of the invention.

BRIEF DESCRIPTION OF FIGURES

- 5 Figure 1a is a block diagram of the hardware layout for the on-board processor form of the radio modem using quadrature modulation and two local oscillators.
- Figure 1b is a block diagram of the hardware layout
10 for an alternative embodiment of the on-board processor form of the radio modem using quadrature modulation and a single local oscillator.
- Figure 2 is a block diagram of the hardware layout for the on-board processor form of the radio modem
15 using baseband modulation.
- Figure 3 is a block diagram of the hardware layout for the microprocessor-less version of the radio modem using baseband modulation and an external interface to the host unit, such as a PCMCIA
20 interface.
- Figure 4 is a block diagram of the operation of the interrupt handler for the power management hardware.
- Figure 5 is a schematic of circuitry that provides a "soft turn-on".
- 25 Figure 6 is timing diagram for the soft turn-on function.
- Figures 7a and 7b relate to the operation of the pre-modulated waveform segment lookup table.

30 DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention are radio modems that can be built into the host unit or attached to a host unit through a

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PCMCIA or similar port. Each radio modem generally comprises transmission/reception means and a modulation/demodulation means.

With reference to Figure 1a, the received
5 signal is conveyed from an antenna (1) via a transmit/receive switch (2) to a bandpass filter (3), which is preferably an electronically-coupled piezoelectric device such as an acoustic wave device and more specifically a SAW, an STW filter, an SSBW
10 filter or what has been commonly referred to a leaky SAW filter. The filtered signal is conveyed to a low-noise amplifier (4) and image filter (5), and to the downconverter (6). In the preferred embodiments, bandpass filters (3) and (5) are SAW
15 filters. Within the downconverter, the signal amplified by a linear amplifier (7) is mixed with a signal (50) from a local oscillator (39) at the mixer (8) to produce a signal (51) at an intermediate frequency greater than or equal to 10.7
20 Mhz. Signal (51) is conditioned by the intermediate frequency (IF) channel filter (9) and is amplified by the IF gain block (10) then conditioned by a noise filter (11). The resulting intermediate frequency signal is demodulated within the
25 demodulator (12). In the preferred embodiment, the intermediate frequency is 45 MHz.

The demodulator consists of a limiting
amplifier (13) to produce a signal having constant amplitude. This signal is split into two parts
30 which are mixed in a mixer (14), with one of the parts shifted in phase relative to the other. The phase shift element (15) is preferably an electronically-coupled piezoelectric device such as

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surface acoustic wave filter or a crystal filter. The demodulated signal is conditioned and converted to a digital representation before being conveyed to a digital signal processor (DSP) (24). The digital
5 signal processor (24) is preferably an ADSP-2171KST-133 commercially available from Analog Devices, Inc., Norwood, Massachusetts. The conditioning and conversion to a digital representation is performed by low pass filter (16), amplified by operational
10 amplifier (17), conditioned by anti-aliasing filter (18) and converted to a digital representation by analog to digital converter (19).

The limiting amplifier (13) produces a second signal (52) with a DC voltage proportional to
15 the received signal strength at the input of the limiter. This signal is referred to as the Received Signal Strength Indicator (RSSI) and is conditioned by low pass filter (20), amplified by operational amplifier (21), conditioned by anti-aliasing filter
20 (22) and converted to a digital representation by analog to digital converter (23).

In the on-board microprocessor form of the invention, the digital data is conveyed to the host unit via the microprocessor (uP) (26), preferably an
25 Intel SB80L188EB-8 (available from Intel Corporation, Santa Clara, California), and a serial communications controller ("SCC") (27), preferably a Phillips SCC 9291 (available from Phillips Electronics North America Corporation, Sunnyvale,
30 California). In the microprocessor-less form of the invention, as seen on figure 3, the modem utilizes the microprocessor of the host (200), and thus there is no need to have a microprocessor resident within

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the externally connected modem, i.e. within the PCMCIA form factor. Additionally, because of the physical connection in the preferred embodiment through the PCMCIA port, the need for an SCC is also
5 eliminated. One of ordinary skill in the art will appreciate that each of the aforementioned components for which particular part numbers are not referenced are well known in the art.

When the radio modem is transmitting, the
10 data to be sent is conveyed from a host data processing unit, via the serial communications controller (27) and the microprocessor (26) to the digital signal processor (24). In the case of quadrature phase modulation, the digital signal
15 processor (24) generates the appropriate in-phase and quadrature-phase modulated waveform segments, which are based on the current and previous bits to be sent, from a precalculated look-up table stored in the associated random-access memory (25). The
20 digital signals are converted to analog signals by two digital-to-analog converters (28) (29), conditioned by two low pass filters (30) (31) and are conveyed to the quadrature modulator (32). Within the quadrature modulator (32) the in-phase
25 signal (53) is mixed in a mixer (33) with the signal from LO1 (36), one of two local oscillators, and the quadrature-phase signal (54) is mixed in a mixer (34) with a ninety-degree phase shifted signal from the local oscillator LO1 (36) supplied via the phase
30 shift element (35). The emerging modulated signal (55) is passed through a band-pass filter (37), and input to an upconverter mixer (38), where it is mixed with a signal (56) from the local oscillator

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LO2 (39). The resulting signal (57) is amplified by exciter amplifier (40), conditioned by a band-pass filter (41), amplified in a three-stage power amplifier (42) and transmitted from the antenna (1) via the transmit/receive switch (2). As can be seen in Figure 1b, the two local oscillators of Figure (1a) can be replaced by a single oscillator (LO) (43) by bypassing the upconversion stage affected by the local oscillators (LO1) (36), (LO2) (39), the mixer (38) and the band pass filter (37).

As illustrated by Figures 2 and 3, in the case of baseband modulation, the digital signal processor (24) similarly generates, from the look-up table store in the associated RAM (25), the appropriate modulation voltage segments for the Voltage Controlled Temperature Compensated Crystal Oscillator (VCTCXO) (201) and the Voltage Controlled Oscillator (VCO) (202). The digital signals thus generated are then converted to modulation voltages by digital to analog converters (28) and (29) and are conditioned by low pass filters (30) and (31). These modulation voltages are applied to the VCO (202) and VCTCXO (201) to shift the local oscillator frequency by a maximum of 2Khz from its nominal frequency. As one of ordinary skill in the art will appreciate, a single D/A converter may perform the functions of the two converters (28) and (29). The resultant local oscillator signal (210) in the baseband modulation scheme is conveyed by splitter (211) to the exciter amplifier (40), conditioned by a band-pass filter (41), amplified in a three-stage power amplifier (42) and is transmitted from the antenna (1) via the transmit/receive switch (2).

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During operation in a baseband modulation configuration, in both the receive and transmit modes, the local oscillator (LO) (208) comprising VCTCXO (201), VCO (202) and synthesizer (209) operates to pass its output signal (210) to both the receive and transmit section of the radio via splitter (211). If the radio modem is in its receive mode, the signal (212) is "ignored" -- the transmit circuitry is not active because of power management and a signal is not conveyed to the antenna (1) as a result of the T/R switch (2). Correspondingly, when the radio modem is in its transmit mode, the LO signal (213) that is transferred via splitter (211) to the receive side is "ignored" -- because the receive circuitry is not active as a result of power management. It should be noted that when the radio modem is in its receive mode, the LO (208) is programmed at the reception frequency, at the beginning of the receive cycle. In the transmit mode, the LO (208) is continuously updated by the VCO and VCTCXO modulation voltages in order to produce the desired frequency shifts required for modulation.

In greater detail, and again with reference to Figures 1a and 1b, 2 and 3, frequency modulation discrimination occurs through the employment of an electronically coupled piezoelectric phase shift element (15), such as a crystal filter. The use of this element represents an improvement over the prior art due to the fact that electronically coupled piezoelectric phase-shift devices have a steeper phase slope relative to changing frequency compared to the resistor inductor

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capacitor (RLC) tank circuits that have been used in the prior art for frequency discrimination. One advantage of the present innovation is that the discriminator can be operated at higher intermediate
5 frequencies, which is of particular importance to this invention, and is discussed in greater detail below. A second advantage is that the steeper phase slope associated with an electronically-coupled phase-shift element makes the resulting
10 discriminator more sensitive, thereby increasing the sensitivity and receiver performance of the radio modem. The use of a frequency modulation discriminator employing an electronically tuned phase shift element is not limited to use within a
15 radio modem. Such means can be used to discriminate any frequency modulated signal in other systems as well. In addition, as one of ordinary skill in the art will appreciate, because of the close relationship between frequency modulation and phase
20 modulation, the frequency modulation discriminator disclosed means could also be used with minor modifications to discriminate a phase modulated signal.

As discussed above, the discriminator
25 disclosed in the present invention is capable of operating with superior performance at higher frequencies than known discriminator designs. An integral part of the innovation for the present invention is preclusion of electrical interference
30 from the host data processing device, such as "software noise", which is a characteristic emission from any running computer. Typically, such noise is of significantly higher amplitude at frequencies

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less than 10.7 MHz. In the present invention, the received signal is down-converted in a single stage to an intermediate frequency that is above the aforementioned threshold frequency of 10.7 MHz, such as 45 MHz. By this method, the radio modem achieves greater noise immunity over known devices, permitting the radio modem to be integrated within a host data processing device without compromising performance of the radio modem.

Again with reference to Figures 1a and 1b, in the case of quadrature modulation, in-phase and quadrature-phase modulated waveform segments are generated by the digital signal processor (24). In the case of baseband modulation, the waveform segments generated are the VCO and VCTCXO modulation voltages. In each case, the waveform segments are based on the current bit, previous bits and future bits to be sent, from a precalculated look-up table stored in the associated random access memory (25). The operation of this method is described below.

As discussed previously, pre-calculated waveforms can be used to eliminate the need to compute complicated formulae at run time. In the case of Gaussian Minimum Phase Shift Keying, as is specified under the Mobitex[™] standard, with a bandwidth time product of 0.3, the actual waveform used to identify a bit is in excess of three bit periods long, as is shown in Figure 7a, for the bit sequence 00100. With reference to Figure 7a, the bit period a (700) and bit period e (701) are affected by the bit in period c (702). Therefore, to store all possible shapes for any bit period c (702), thirty-two different segments are required to

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represent all possible values for the five bit periods shown. By realizing that the significant portion of the Gaussian shape is only four bit periods long, and by shifting the waveform by half of one bit, the number of table entries can be reduced by half to sixteen. The segments are centered on one interbit period (703), as shown in Figure 7b. With reference to Figure 7b, the bit center (704) is positioned between the bit period c (705) and the bit period d (706). Therefore the value of segment c (705) is only affected by the values of four bits, and therefore has only sixteen possible shapes.

The method described above yields baseband, but not in phase and quadrature phase signals. If baseband modulation is desired, no further calculations are needed. For quadrature modulation, however, the I and Q signals must be calculated from the tabulated data described above, using the following approach. The in-phase and quadrature phase signals depend on the initial phase at the beginning of the bit period. This initial phase must be known when the tables are calculated. In the Mobitex™ system, the modulation is such that the frequency difference between a stream of continuous 1's and a stream of continuous 0's is an even fraction of the bit rate constraining the starting phase to one of a discrete set of values. For example, in Mobitex™, the frequency deviation is 2000 Hz and the baudrate is 8000 bits/second. Thus, a 1 transmitted previously will cause a phase shift in the modulated signal of 90 degrees, whereas a 0 transmitted previously will cause a phase shift of -

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90 degrees. There are four multiples of 90 degree phase shifts, or four possible distinct starting phases for each wave segment for a given surrounding four bit sequence. The rotation of a Cartesian
5 vector by steps of 90 degrees is a simple operation and can be easily calculated as required. No additional precomputed samples are required to accommodate different starting phases. In particular, only trivial trigonometric calculations
10 or look-up tables are required.

Power Management

The present invention also employs innovative power management means and methods, in
15 order to minimize power consumption. Although such power management techniques are directed to the on-board processor form of the instant invention, one of ordinary skill in the art could recognize their applicability, albeit with potentially reduced power
20 savings, if the techniques were incorporated into the microprocessor-less form of the invention.

The major components of the power management circuit are the serial communications controller (27), incorporating an integrated timer
25 and memory, and microprocessor (26), as shown in Figures 1a and 1b. Through implementation of the power management means, the radio modem circuitry consumes approximately one half the power of other known systems. In general, maximum power savings in
30 any situation are accomplished by completely turning the device off. The microprocessor (26) has the ability to enter a dormant mode of operation where it consumes virtually no power. The circuit has

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been implemented such that the processor can also shut down other circuitry that is not in use. The processor is brought back to active mode by activating reset or providing an external non-
5 maskable interrupt signal.

The present invention utilizes a system that allows the processor to shut down most of the circuitry, but remains able to power-up on one of two conditions, namely, that either a pre-determined
10 time had elapsed, or that the host system attempts to communicate. Both of these conditions are problematic, requiring innovative solutions, which are as follows:

15 *Timer System*

In order to "wake up" the microprocessor and, subsequently, the digital signal processor, a programmable timer circuit, external to the microprocessor, is set such that it produces an
20 output pulse to the processor after the expiration of a selectable, predetermined time period. As seen in Figure 4 in block (401), the timer is set when it is determined that the microprocessor does not have any tasks left to be completed in its task list
25 therefore the microprocessor and the digital signal processor are permitted enter their lowest power mode. Although in the preferred embodiment the microprocessor when directed to shut down first shuts down the digital signal processor before
30 shutting itself down, it would be appreciated by one of ordinary skill in the art that the digital signal processor could first determine that it is able to

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shut down, and then advise the microprocessor to shut down.

Communication System

5 In most applications, the host data processing system or data communication system communicates with the circuit at a very high rate, often exceeding 9600 bits per second. When the host begins communicating, the circuit has only about
10 1 millisecond to initialize to prevent information from being lost. By using a serial communications controller (27) with a built in memory, it is possible to store the first few characters external to the processor. This allows the processor over
15 four times longer to initialize and respond to the host.

Masking the Non-Maskable Interrupt

 If the external serial communications
20 controller were connected directly to the non-maskable interrupt of the processor, inefficient operation would result as an non-maskable interrupt requires longer to service than a standard interrupt. To overcome this problem, the non-
25 maskable interrupt is connected through standard logic gates to provide a masking operation. By enabling the processor to mask the non-maskable interrupt, faster response time, reduced processor 'on' time in a fully-powered state, and lower power
30 consumption result. Masking a non-maskable interrupt for the purposes of power saving is previously unknown in the prior art.

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Power Management Software Description

The Power Management Software contains several key components, the most important of these is the task list. As suggested by Figure 4, if the processor or associated circuitry is 'busy' with a task, it will be indicated by an entry in the task list. When the task list becomes empty the processor will enter the lowest power mode possible, and as seen in block (401) of Figure 4, the serial controller is posted as a sentry to detect data communications so as to initiate an activating interrupt to the microprocessor to begin an activation cycle. Additionally, the timer associated with the serial communications controller (27) is set to initiate an output pulse that will also serve to activate the microprocessor prior to the initiation of the activating interrupt by the serial communications controller (27). In normal operation under this power management scheme, the processor spends about 5% of its time active, and 95% in the fully idle, lowest power mode.

One of the key elements in the software system is improvement to the interrupt handler. Normally, in existing systems, software would return to the instruction following the point at which the interrupt occurred. However, there is a window of vulnerability when using a maskable non-maskable interrupt as previously described. If an interrupt occurs at the instant that the interrupt is unmasked (unexpected non-maskable interrupt), and the interrupt handler was written in the manner of prior existing systems, program execution would return to the instruction following where the interrupt

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occurred. In this case, the instruction would be a halt instruction. Therefore, the processor would be caused to halt execution by an interrupt, when what is required is an interrupt that initiates
5 execution. As seen in blocks (402), (403) and (404) of Figure 4, the present invention incorporates modifications to the standard operation of the processor by modifying the program stack and forcing the code to execute from a specific known state that
10 would be 'safe' after either an expected, or unexpected non-maskable interrupt. The unexpected result of implementing the above power management scheme combined with the previously described circuit that includes a serial communications
15 controller (27) to provide a masked nonmaskable interrupt, is the power consumption for continuous operation of the serial communications controller (27) is dramatically less than the power requirement of the microprocessor and the digital signal
20 processor. In the preferred embodiment, the overall system power requirement was reduced by a factor of more than 6.

Soft "Turn-on" Operation

25 The function of the soft "turn-on" circuit is to allow the host to turn the radio on and off with a minimum of extra circuitry. The soft turn-on is required to be rugged in the sense that it should not accidentally turn on or off when variations in
30 supplied power occur. The quiescent power dissipation of the circuit must be as low as possible, especially when the circuit is in its off state. The circuit is required to operate at

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varying supply voltages, such as when the system battery is substantially discharged or overcharged, with the circuit most importantly maintaining correct operation of the radio modem by keeping the
5 radio off or on as desired. Standard off-the shelf components and circuits generally have undefined operation below a few volts making them unsuitable for this purpose.

The circuit used to achieve the above goal
10 is shown in Figure 5. The circuit is similar in operation to an RS flip-flop that satisfies the additional operational constraints:

1) When the host 'Turnon' signal (500) is active, power is supplied to the radio modem through
15 microprocessor power supply (502) which is preferably a LT1121ACS8-5 manufactured by Linear Technology, Miltitas, California. As seen in the timing diagram Figure 6, a period of time elapses from the time the Turnon signal is initiated to the
20 time the power supply is reaches operating voltage.

2) When the on indication ('ONI') signal (501) is active while Turnon signal (500) goes from active to in-active, power remains supplied until both control power down functions are completed and the
25 Turnon signal (500) is determined to be constantly active. Also, as Figure 6 illustrates, the ONI signal (601) remains in an inactive state until the radio modem has completed its initialization cycle and remains active until the expiration of the
30 control power down cycle.

3) When the host 'Turnon' signal (500) is inactive, power will only be removed from the circuit if 'ONI' is also inactive. This is

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illustrated as well on Figure 6 at the point (600) where the control power down cycle ends.

- 4) A brief transition of 'ONI' from inactive to active while 'Turnon' is inactive will not cause
5 power to be applied to the circuit as also displayed in Figure 6.

Waveform Table Generating and DSP Software

- As discussed previously, the waveform
10 tables were generated from two software modules that can be found, in source code form in Appendix A. In Appendix B, can be found the software used to process the received signals and to generate the transmitted signals. Although the invention is
15 fully described in the specification without reference to the appended source code modules, the Appendices are presented to provide further insight into the advancement over the prior art.

- Although the present invention has been
20 described and illustrated in detail, the description is meant to be illustrative and not limiting the spirit or scope of the invention, which is limited and defined with particularity only by the terms of the appended claims.

APPENDIX A

WAVEFORM TABLE GENERATING SOFTWARE AND ASSOCIATED TABLES

I. Table-building Module (Modtab.C)

```

#include <stdio.h>
#include <stdlib.h>
#include <conio.h>
#include <math.h>
#define TRUE 1
#define FALSE 0
// Mode variables for controlling what the program does
static int bGraphit; static int bBaseband; static int
GaussianFullScale; static int bBasestation; static int
correct_samples_flag;
#define GREEN      2
#define CYAN       3
#define RED        4
#define BRWHITE 15
#define BLUE       1
#define WHITE      7

void SetGraphParameters(long MinVal, long MaxVal, int
TimeScale, int NumSamples, char Title[]);
void GraphFunction(int Function[], int color);
void Graph2Function(int Function1[], int Function2[], int
color);

void TimeMark(int SamplePoint, int bBetween, int color);
void SetHiresMode(void); void SetTextMode(void);
#define OVERSAMPLING 20
#define SAMPLING_FREQUENCY (double) 8000 * OVERSAMPLING
#define RESISTANCE          (double) 3920
#define CAPACITANCE         (double) 0.00000001011
#define CORRECTION_FACTOR 0.75
#define GAUSSLENGTH (OVERSAMPLING * 5)
#define GAUSSFULLSCALE 8000 // Total length of a gmsk

```

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```

#define BTSCALE 1.6
#define IANDQFULLSCALE 0x7FFF
#define PI 3.14159
#define BITRATE 8000
#define FILTER_R 3290
#define FILTER_C 6.8e-9
#define TIMECONST (FILTER_R * FILTER_C * 2 * PI)
int Gaussian[GAUSSLENGTH];
int GmskShape[GAUSSLENGTH + OVERSAMPLING*4];
int IShape[GAUSSLENGTH + OVERSAMPLING*4];
int QShape[GAUSSLENGTH + OVERSAMPLING*4];
int ITables[2*2*2*2*OVERSAMPLING];
int QTables[2*2*2*2*OVERSAMPLING];
int IStartTable[OVERSAMPLING*3];
int QStartTable[OVERSAMPLING*3];
struct {
    int * IPointer; int * QPointer; int ISign;
    int QSign;
} IQInit[4];
// Generates the master gaussian wave shape used later.
static void BuildGaussian(void)
{
    float power; int a,b;
    if (bGraphit){
        SetGraphParameters(0, GaussianFullScale,
16*10, GAUSSLENGTH, "Natural and Modified Gaussian shapes");
        for (a=0; a<=5; a++){
            TimeMark(OVERSAMPLING*a-1, -1, RED);
        }
        for (a=0; a<GAUSSLENGTH; a++){
            power = (a-((float)GAUSSLENGTH-2)/2) / OVERSAMPLING;
            power = -(power*power);
            Gaussian[a] = (int) (((long)GaussianFullScale*2)/3) *
exp(power * BTSCALE));
        }
        if (bGraphit) GraphFunction(Gaussian, GREEN);
        // Normalize the gaussian with an 8 khz rate.
        for (a=0; a<OVERSAMPLING; a++){

```

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```

    long Sum;    Sum = 0;
    for (b=0;b<GAUSSLENGTH;b+= OVERSAMPLING){
        Sum += Gaussian[a+b];    }
    for (b=0;b<GAUSSLENGTH;b+= OVERSAMPLING){
        Gaussian[a+b] = (int)((Gaussian[a+b] *
(long)GaussianFullScale) / Sum);
    } }
    if (bGraphit){
        GraphFunction(Gaussian, CYAN);
        getch();
    }
}
// Builds a GMSK waveform from four bits specified
static void BuildGMSK(int BitArray[])
{
    int a,bit;
    for (a=0;a<GAUSSLENGTH + OVERSAMPLING*4;a++){
        GmskShape[a] = 0;
    }
    for (bit=0;bit<4;bit++){
        for (a=0;a<GAUSSLENGTH;a++){
            if (BitArray[bit] == 1) GmskShape[bit*OVERSAMPLING
+ a] += Gaussian[a];
            if (BitArray[bit] == 0) GmskShape[bit*OVERSAMPLING
+ a] -= Gaussian[a];
        } } }
// Takes the waveform in GmskShape and I and Q modulates it
into IandQShape.
static void IandQModulate(void)
{
    double phase;  int a;  phase = 0;
    if (bBaseband){
        for (a=0;a<GAUSSLENGTH + OVERSAMPLING*4; a++){
            IShape[a] = GmskShape[a];
            QShape[a] = -GmskShape[a];
        } } else{
        for (a=0;a<GAUSSLENGTH + OVERSAMPLING*4;a++){
            IShape[a] = (int)(IANDQFULLSCALE * sin(phase));
            QShape[a] = (int)(IANDQFULLSCALE * cos(phase));

```

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```

        phase += GmskShape[a] * (PI / OVERSAMPLING /
GaussianFullScale / 2);
    } } }

static
void
correct_samples( void )
{
    int a; double k; double temp; double I_temp;
    double Q_temp;
    k = exp( (double) ( (double) (-1) / (double)
(SAMPLING_FREQUENCY * RESISTANCE * CAPACITANCE) ) );
    I_temp = IShape[ 0 ]*CORRECTION_FACTOR;
    Q_temp = QShape[ 0 ]*CORRECTION_FACTOR;
    for( a=1; a<GAUSSLENGTH + OVERSAMPLING*4; a++ ) {
        temp = IShape[ a ]*CORRECTION_FACTOR;
        IShape[a] = (int)(( temp - k * I_temp ) / ( 1 - k ));
        I_temp = temp;
        temp = QShape[ a ]*CORRECTION_FACTOR;
        QShape[a] = (int)(( temp - k * Q_temp ) / ( 1 - k ));
        Q_temp = temp;
    }
}

static void BuildSegments(void)
{
    int Array[4];int a;int BaseIndex;
    if (bGraphit){
        SetGraphParameters(-IANDQFULLSCALE,
IANDQFULLSCALE, 16*10, GAUSSLENGTH + OVERSAMPLING*2,
        "Iand Q patterms");
    }
    for (Array[0] = 0;Array[0] < 2;Array[0]++){
        for (Array[1] = 0;Array[1] < 2;Array[1]++){
            for (Array[2] = 0;Array[2] < 2;Array[2]++){
                for (Array[3] = 0;Array[3] < 2;Array[3]++){
                    BuildGMSK(Array);
                    IandQModulate();
                    if( correct_samples_flag ) {
                        correct_samples();
                    }
                    if (bGraphit){
                        for (a=0;a<9;a++){

```

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```

                                TimeMark(OVERSAMPLING*a, -1,
BLUE);

                                }
                                GraphFunction(GmskShape, RED);
                                GraphFunction(IShape, CYAN);
                                GraphFunction(QShape, GREEN);
                                }
                                BaseIndex = (Array[3] + Array[2]*2 +
Array[1]*4 + Array[0]*8) * OVERSAMPLING;
                                /* Take the data from between the second and third bits,
where it is least influenced by undetermined outside bits.
These segments will later be used to piece together I and Q
data for regular modulation. */
                                for (a=0;a<OVERSAMPLING;a++){
                                        ITables[BaseIndex+a] =
IShape[OVERSAMPLING*3 + OVERSAMPLING/2 + a];
                                        QTables[BaseIndex+a] =
QShape[OVERSAMPLING*3 + OVERSAMPLING/2 + a];
                                } } } } }
                                if (bGraphit) getch();
/* Now build the table for the startup sequence, based on a
110011001100 bit sync starting sequence. Startup is special
as it is not surrounded by bits on the left side, which makes
a slight difference in the gaussian and I and Q segments. */
                                if (bBasestation){
                                        Array[0] = 1;   Array[1] = 1;
                                        Array[2] = 0;   Array[3] = 0;
                                }else{
                                        Array[0] = 0;   Array[1] = 0;
                                        Array[2] = 1;   Array[3] = 1;
                                }
                                BuildGMSK(Array);
                                IandQModulate();
                                /* Copy the segments safely away into a storage array.
Segments are already in their proper order. */
                                for (a=0;a<OVERSAMPLING*3;a++){
                                        IStartTable[a] = IShape[a+OVERSAMPLING/2];
                                        QStartTable[a] = QShape[a+OVERSAMPLING/2];

```

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```

    } }
// Function to initialize the table offsets for different
// starting phases.
void InitPhaseIndices(void)
{ if (bBaseband){
    IQInit[0].IPointer = ITables;
    IQInit[0].QPointer = QTables;
    IQInit[0].ISign = 1; IQInit[0].QSign = 1;
    IQInit[1].IPointer = ITables;
    IQInit[1].QPointer = QTables;
    IQInit[1].ISign = 1; IQInit[1].QSign = 1;
    IQInit[2].IPointer = ITables;
    IQInit[2].QPointer = QTables;
    IQInit[2].ISign = 1; IQInit[2].QSign = 1;
    IQInit[3].IPointer = ITables;
    IQInit[3].QPointer = QTables;
    IQInit[3].ISign = 1; IQInit[3].QSign = 1;
} else {
    IQInit[0].IPointer = ITables;
    IQInit[0].QPointer = QTables;
    IQInit[0].ISign = 1; IQInit[0].QSign = 1;
    IQInit[1].IPointer = QTables;
    IQInit[1].QPointer = ITables;
    IQInit[1].ISign = 1; IQInit[1].QSign = -1;
    IQInit[2].IPointer = ITables;
    IQInit[2].QPointer = QTables;
    IQInit[2].ISign = -1; IQInit[2].QSign = -1;
    IQInit[3].IPointer = QTables;
    IQInit[3].QPointer = ITables;
    IQInit[3].ISign = -1; IQInit[3].QSign = 1;
}}
void TestModulate()
{ int BitHistory;
  int SamplesLeft;
  int StartingPhase;
  int * IPointer, * QPointer;      // I & Q pointers
  int ISign, QSign;                // I & Q Signs
  int SourceBits[25];

```

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```

static int OutputI[OVERSAMPLING*21];
static int OutputQ[OVERSAMPLING*21];
int Sample;           // Modulated sample count
int BitIndex;
// Generate a series of bits
for (BitIndex=0;BitIndex<25;BitIndex++){
    SourceBits[BitIndex] = 0; }
SourceBits[2] = 1; SourceBits[3] = 1;
SourceBits[4] = 1; SourceBits[5] = 1;
SourceBits[9] = 1; SourceBits[11] = 1;
/* Set up the starting sequence of moving from carrier to
bitsync. This is different from regular bits, as the non bits
(neutral bits) have a different effect on the I and Q segments
to be used than regular bits would. We use a special Starting
sequence, which assumes that the start of the modulation is
1100, the start of the mobile bitsync! */
if (bBasestation){
    SamplesLeft = OVERSAMPLING * 3;
    IPointer = IStartTable; QPointer = QStartTable;
    ISign = 1; QSign = 1; BitHistory = 6;
    StartingPhase = 1; BitIndex = 3;
}else{
    SamplesLeft = OVERSAMPLING * 3;
    IPointer = IStartTable;QPointer = QStartTable;
    ISign = 1; QSign = 1; BitHistory = 1;
    StartingPhase = 1; BitIndex = 3;
} // Generate the waveform by sending out segments of
the precalculated tables.
for (Sample = 0;Sample<OVERSAMPLING*21;Sample++){
    if (SamplesLeft == 0){
        if (BitHistory & 8){
            StartingPhase = (StartingPhase + 1) & 3;
        }else{
            StartingPhase = (StartingPhase - 1) & 3;
        } // Shift the bits currently under
consideration to accomodate new bit. MSB is discarded (its
phase contribution is already accounted for).

```

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```

        BitHistory = ((BitHistory << 1) +
SourceBits[BitIndex++]) & 15;
        IPointer = BitHistory * OVERSAMPLING +
IQInit[StartingPhase].IPointer;
        QPointer = BitHistory * OVERSAMPLING +
IQInit[StartingPhase].QPointer;
        ISign = IQInit[StartingPhase].ISign;
        QSign = IQInit[StartingPhase].QSign;
        // Now have OVERSAMPLING samples before this
calculation needs repetition.
        SamplesLeft = OVERSAMPLING;
        // Crank out one sample at a time, until its time to
select a new segment.
        SamplesLeft -= 1;
        OutputI[Sample] = *(IPointer++) * ISign;
        OutputQ[Sample] = *(QPointer++) * QSign;
    }
    if (bGraphit){ nt a;
        SetGraphParameters(-IANDQFULLSCALE, IANDQFULLSCALE,
16*10, OVERSAMPLING*16, "I and Q segments");
        for (a=0;a<16;a++){
            TimeMark(OVERSAMPLING*a, -1, RED);
        }
        GraphFunction(OutputI, CYAN);
        GraphFunction(OutputQ, GREEN);
        for (a=OVERSAMPLING*16;a>0;a--){
            OutputI[a] = (OutputI[a]-OutputI[a-1]) *
(OVERSAMPLING/2);
            OutputQ[a] = (OutputQ[a]-OutputQ[a-1]) *
(OVERSAMPLING/2);
        }
        getch();
        SetGraphParameters(-IANDQFULLSCALE, IANDQFULLSCALE,
16*10, OVERSAMPLING*16, "I and Q slopes");
        for (a=0;a<16;a++){
            TimeMark(OVERSAMPLING*a, -1, RED);
        }
        GraphFunction(OutputI, CYAN);

```

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```

        GraphFunction(OutputQ, GREEN);
        getch();
    })

static void Usage()
{
    printf("usage of modtab program:\n"
        "modtab [-b] [-g]\n"
        "where:\n"
        "    -b  Indicates baseband graph\n"
        "    -g  Indicates graphing enabled\n"
        "    -t  Indicates base transmit\n"
        "    -i  use ideal samples\n" );
    exit(0);}

// Main program
void main( int argc, char *argv[] )
{
    int a; char * outfilename = "moddata.h";
    FILE *outfile;
    bGraphit = FALSE; bBaseband = FALSE;
    bBasestation = FALSE;
    GaussianFullScale = GAUSSFULLSCALE;
    correct_samples_flag = TRUE;
    for (a = 1; a < argc; a++) {
        if (argv[a][0] == '/' || argv[a][0] == '-') {
            switch (argv[a][1]) {
                case 'g':
                case 'G':
                    printf("Graphing enabled\n");
                    bGraphit = TRUE;
                    break;
                case 'b':
                case 'B':
                    printf("Baseband instead of I and Q\n");
                    bBaseband = TRUE;
                    break;
                case 'f':
                case 'F':
                    printf("Full scale baseband enabled\n");
                    GaussianFullScale = IANDQFULLSCALE;
            }
        }
    }
}

```

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```

        break;
    case 't':
    case 'T':
        printf( "Base station transmit sequence\n"
);
        bBasestation = TRUE;
        break;
    case 'i':
    case 'I':
        printf( "Using ideal samples\n" );
        correct_samples_flag = FALSE;
        break;
    case 'o':
    case 'O':
        printf("creating output file
'%s'\n",argv[a]+2);
        outfilename = argv[a]+2;
        goto skipcheck;
    default:
        Usage();
    }
    if (argv[a][2]) Usage();
skipcheck:;
    }else{
        Usage();
    } }
    if (bGraphit) SetHiresMode();
    BuildGaussian();
    BuildSegments();
    InitPhaseIndices();
    TestModulate();
    if (bGraphit){
        SetGraphParameters(-IANDQFULLSCALE, IANDQFULLSCALE,
16*10, OVERSAMPLING*16,"I and Q segments");
        for (a=0;a<16;a++){
            TimeMark(OVERSAMPLING*a, -1, RED);
        }
        GraphFunction(ITables, CYAN);

```

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```

        GraphFunction(QTables, GREEN);
        getch(); }
    if (bGraphit) SetTextMode();
    outfile = fopen(outfilename, "w");
    if( outfile == NULL )
    {   printf("Failed to create '%s'\n", outfilename);
        exit(1); }
    fprintf(outfile, "/*\n");
    fprintf(outfile, " * %s: was created using the command
line:\n", outfilename);
    fprintf(outfile, " * ");
    for (a=0; a<argc; a++){
        fprintf(outfile, "%s ", argv[a]); }
    fprintf(outfile, "\n *\n");
    if (bBaseband){
        fprintf(outfile, " * This file is BASEBAND\n");
    }else{
        fprintf(outfile, " * This file is I and Q\n");
    }
    fprintf(outfile, " */\n\n");
    // if (bBaseband) fprintf(outfile, "#define BASEBAND 1\n");

    fprintf(outfile, ".INIT I_samples:\n");
    for( a = 0; a < 16*OVERSAMPLING; a+= 4 )
    {   fprintf(outfile, "\t\t0x%.4x00, 0x%.4x00, 0x%.4x00,
0x%.4x00", ITables[a], ITables[a+1], ITables[a+2], ITables[a+3]);
        if( a < 16*OVERSAMPLING - 4 ) {
            fprintf(outfile, ",\n"); } }
    fprintf(outfile, ";\n\n");
    fprintf(outfile, ".INIT Q_samples:\n");
    for( a = 0; a < 16*OVERSAMPLING; a+= 4 )
    {   fprintf(outfile, "\t\t0x%.4x00, 0x%.4x00, 0x%.4x00,
0x%.4x00", QTables[a], QTables[a+1], QTables[a+2], QTables[a+3] );
        if( a < 16*OVERSAMPLING - 4 )
        {   fprintf(outfile, ",\n"); } }
#ifdef NEVER
    {   int Sample; long MaxMag; long MinMag;
        int MinSample; int MaxSample; long Mag;
        long ISum; long QSum; long IAvG;

```

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```

    long QAvg; MinMag = 0x7FFFFFFF;
    MaxMag = 0x80000000; MinSample = 0x7FFF;
    MaxSample = 0x8000; ISum = 0; QSum = 0;
    for (Sample = 0; Sample < 16*OVERSAMPLING; Sample++) {
        Mag = ((long)ITables[Sample]) *
        ((long)ITables[Sample])
            + ((long)QTables[Sample]) *
        ((long)QTables[Sample]);
        if (MaxMag < Mag) MaxMag = Mag;
        if (MinMag > Mag) MinMag = Mag;
        printf("Mag: %ld MinMag: %ld MaxMag: %ld\n", Mag,
MinMag, MaxMag);
        if (MaxSample < ITables[Sample]) MaxSample =
ITables[Sample];
        if (MaxSample < QTables[Sample]) MaxSample =
QTables[Sample];
        if (MinSample > ITables[Sample]) MinSample =
ITables[Sample];
        if (MinSample > QTables[Sample]) MinSample =
QTables[Sample];
        ISum = ISum + ITables[Sample];
        QSum = QSum + ITables[Sample];    }
    IAvg = ISum / 16*OVERSAMPLING;
    QAvg = QSum / 16*OVERSAMPLING;
    printf("MinSample: %d MaxSample
%d\n", MinSample, MaxSample);
    printf("ISum: %ld QSum: %ld IAvg: %ld QAvg:
%ld\n", ISum, QSum, IAvg, QAvg);
    printf("MagError:
%f%%\n", (((double)MaxMag/(double)MinMag-1)*100));
    getch();
    return; }
#endif

    fprintf(outfile, ";\n\n");
    fprintf(outfile, ".INIT initial_I_samples:\n");
    for( a = 0; a < 3*OVERSAMPLING; a+= 3 ) {
        fprintf(outfile, "\t\t0x%.4x00, 0x%.4x00,
0x%.4x00", IStartTable[a], IStartTable[a+1], IStartTable[a+2]);

```

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```

        if( a < 3*OVERSAMPLING - 3 )
        { fprintf(outfile, "\n"); } }
    fprintf(outfile, "; \n \n");
    fprintf(outfile, ".INIT initial_Q_samples: \n");
    for( a = 0; a < 3*OVERSAMPLING; a+= 3 )
    { fprintf(outfile, "\t\t0x%.4x00, 0x%.4x00,
0x%.4x00", QStartTable[a], QStartTable[a+1], QStartTable[a+2]);
        if( a < 3*OVERSAMPLING - 3 )
        { fprintf(outfile, "\n"); } }
    fprintf(outfile, "; \n"); fprintf(outfile, "\n");
    if (bBaseband){
        fprintf(outfile, ".INIT carrier_I_sample:
0x000000; \n");
        fprintf(outfile, ".INIT carrier_Q_sample:
0x000000; \n");
    }else{
        fprintf(outfile, ".INIT carrier_I_sample:
0x000000; \n");
        fprintf(outfile, ".INIT carrier_Q_sample:
0x7fff00; \n"); }
    fprintf(outfile, "\n"); exit( 0 );}

```

II. Table for Quadrature Phase Modulation

```

/* obj\moddatiq.h: was created using the command line:
 * obj\modtab.exe -i -oobj\moddatiq.h
 * The data is in the 16 MSB of the 24 bit words, which
 * are used by the DSP when getting data from program
 * memory. */

```

.INIT I_samples:

```

    0xa91100, 0xb0b200, 0xb8d100, 0xc16000,
    0xca5300, 0xd39a00, 0xdd2800, 0xe6ec00,
    0xf0d800, 0xfadc00, 0x04e700, 0x0eeb00,
    0x18d800, 0x229e00, 0x2c2d00, 0x357600,
    0x3e6b00, 0x46fc00, 0x4f1e00, 0x56c200,
    0xa90500, 0xb0a000, 0xb8b400, 0xc13500,
    0xca1400, 0xd34000, 0xdca900, 0xe63d00,
    0xefeb00, 0xf99f00, 0x034700, 0x0ccf00,
    0x162500, 0x1f3600, 0x27f200, 0x304500,

```

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0x382400, 0x3f7f00, 0x464d00, 0x4c8500,
0x9de800, 0xa25300, 0xa69c00, 0xaaa800,
0xae5f00, 0xb1aa00, 0xb47300, 0xb6ad00,
0xb84a00, 0xb94300, 0xb99600, 0xb94700,
0xb85d00, 0xb6e700, 0xb4f300, 0xb29700,
0xafea00, 0xad0400, 0xa9fd00, 0xa6ee00,
0x9dde00, 0xa24300, 0xa68300, 0xaa8300,
0xae2a00, 0xb15e00, 0xb40a00, 0xb61b00,
0xb78500, 0xb83c00, 0xb83c00, 0xb78500,
0xb61b00, 0xb40a00, 0xb15e00, 0xae2a00,
0xaa8300, 0xa68300, 0xa24300, 0x9dde00,
0xa70300, 0xaa1400, 0xad1b00, 0xb00200,
0xb2af00, 0xb50c00, 0xb70000, 0xb87700,
0xb96000, 0xb9b000, 0xb95c00, 0xb86300,
0xb6c600, 0xb48c00, 0xb1c200, 0xae7600,
0xaabf00, 0xa6b200, 0xa26800, 0x9dfc00,
0xa70f00, 0xaa2500, 0xad3500, 0xb02800,
0xb2e700, 0xb55900, 0xb76c00, 0xb90b00,
0xba2800, 0xbaba00, 0xbaba00, 0xba2800,
0xb90b00, 0xb76c00, 0xb55900, 0xb2e700,
0xb02800, 0xad3500, 0xaa2500, 0xa70f00,
0xb35600, 0xb98600, 0xc04900, 0xc79500,
0xcf5e00, 0xd79700, 0xe02d00, 0xe90e00,
0xf22500, 0xfb5e00, 0x04a200, 0x0ddb00,
0x16f200, 0x1fd300, 0x286900, 0x30a200,
0x386b00, 0x3fb700, 0x467a00, 0x4caa00,
0xb36300, 0xb99a00, 0xc06700, 0xc7c100,
0xcf9f00, 0xd7f200, 0xe0ac00, 0xe9bd00,
0xf31300, 0xfc9b00, 0x064200, 0x0ff700,
0x19a500, 0x233a00, 0x2ca300, 0x35d100,
0x3eb000, 0x473200, 0x4f4800, 0x56e400,
0x4c9d00, 0x466600, 0x3f9900, 0x383f00,
0x306100, 0x280e00, 0x1f5400, 0x164300,
0x0ced00, 0x036500, 0xf9be00, 0xf00900,
0xe65b00, 0xdcc600, 0xd35d00, 0xca2f00,
0xc15000, 0xb8ce00, 0xb0b800, 0xa91c00,
0x4caa00, 0x467a00, 0x3fb700, 0x386b00,
0x30a200, 0x286900, 0x1fd300, 0x16f200,

0x0ddb00, 0x04a200, 0xfb5e00, 0xf22500,
 0xe90e00, 0xe02d00, 0xd79700, 0xcf5e00,
 0xc79500, 0xc04900, 0xb98600, 0xb35600,
 0x58f100, 0x55db00, 0x52cb00, 0x4fd800,
 0x4d1900, 0x4aa700, 0x489400, 0x46f500,
 0x45d800, 0x454600, 0x454600, 0x45d800,
 0x46f500, 0x489400, 0x4aa700, 0x4d1900,
 0x4fd800, 0x52cb00, 0x55db00, 0x58f100,
 0x58fd00, 0x55ec00, 0x52e500, 0x4ffe00,
 0x4d5100, 0x4af400, 0x490000, 0x478900,
 0x46a000, 0x465000, 0x46a400, 0x479d00,
 0x493a00, 0x4b7400, 0x4e3e00, 0x518a00,
 0x554100, 0x594e00, 0x5d9800, 0x620400,
 0x622200, 0x5dbd00, 0x597d00, 0x557d00,
 0x51d600, 0x4ea200, 0x4bf600, 0x49e500,
 0x487b00, 0x47c400, 0x47c400, 0x487b00,
 0x49e500, 0x4bf600, 0x4ea200, 0x51d600,
 0x557d00, 0x597d00, 0x5dbd00, 0x622200,
 0x621800, 0x5dad00, 0x596400, 0x555800,
 0x51a100, 0x4e5600, 0x4b8d00, 0x495300,
 0x47b600, 0x46bd00, 0x466a00, 0x46b900,
 0x47a300, 0x491900, 0x4b0d00, 0x4d6900,
 0x501600, 0x52fc00, 0x560300, 0x591200,
 0x56fb00, 0x4f6000, 0x474c00, 0x3ecb00,
 0x35ec00, 0x2cc000, 0x235700, 0x19c300,
 0x101500, 0x066100, 0xfcb900, 0xf33100,
 0xe9db00, 0xe0ca00, 0xd80e00, 0xcfbb00,
 0xc7dc00, 0xc08100, 0xb9b300, 0xb37b00,
 0x56ef00, 0x4f4e00, 0x472f00, 0x3ea000,
 0x35ad00, 0x2c6600, 0x22d800, 0x191400,
 0x0f2800, 0x052400, 0xfb1900, 0xf11500,
 0xe72800, 0xdd6200, 0xd3d300, 0xca8a00,
 0xc19500, 0xb90400, 0xb0e200, 0xa93e00;

.INIT Q_samples:

0xa20f00, 0x9b8900, 0x95a000, 0x905f00,
 0x8bce00, 0x87f400, 0x84d700, 0x827d00,
 0x80e800, 0x801c00, 0x801a00, 0x80e100,

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0x827100, 0x84c700, 0x87df00, 0x8bb500,
0x904200, 0x957f00, 0x9b6300, 0xa1e600,
0xa21a00, 0x9b9800, 0x95b400, 0x907800,
0x8beb00, 0x881500, 0x84fb00, 0x82a000,
0x810500, 0x802a00, 0x800c00, 0x80a600,
0x81f000, 0x83df00, 0x866600, 0x897500,
0x8cfa00, 0x90de00, 0x950a00, 0x996600,
0xadc800, 0xa8c800, 0xa46500, 0xa09d00,
0x9d6a00, 0x9ac800, 0x98af00, 0x971700,
0x95fc00, 0x955400, 0x951e00, 0x955200,
0x95ee00, 0x96ef00, 0x985200, 0x9a1100,
0x9c2800, 0x9e8e00, 0xa13700, 0xa41500,
0xadd400, 0xa8d900, 0xa47d00, 0xa0be00,
0x9d9700, 0x9b0200, 0x98fc00, 0x977e00,
0x968200, 0x960500, 0x960500, 0x968200,
0x977e00, 0x98fc00, 0x9b0200, 0x9d9700,
0xa0be00, 0xa47d00, 0xa8d900, 0xadd400,
0x5c0000, 0x5ede00, 0x618600, 0x63eb00,
0x660100, 0x67c000, 0x692200, 0x6a2300,
0x6abf00, 0x6af300, 0x6abc00, 0x6a1500,
0x68fa00, 0x676300, 0x654b00, 0x62a900,
0x5f7800, 0x5bb000, 0x574e00, 0x525000,
0x5c0b00, 0x5eee00, 0x619c00, 0x640a00,
0x662b00, 0x67f800, 0x696d00, 0x6a8600,
0x6b4200, 0x6ba000, 0x6ba000, 0x6b4200,
0x6a8600, 0x696d00, 0x67f800, 0x662b00,
0x640a00, 0x619c00, 0x5eee00, 0x5c0b00,
0x667e00, 0x6ad800, 0x6f0200, 0x72e300,
0x766500, 0x797200, 0x7bf900, 0x7dec00,
0x7f3e00, 0x7fe900, 0x7fe900, 0x7f3e00,
0x7dec00, 0x7bf900, 0x797200, 0x766500,
0x72e300, 0x6f0200, 0x6ad800, 0x667e00,
0x668800, 0x6ae500, 0x6f1300, 0x72f900,
0x767f00, 0x799000, 0x7c1a00, 0x7e0b00,
0x7f5700, 0x7ff300, 0x7fd700, 0x7eff00,
0x7d6600, 0x7b0d00, 0x77f500, 0x742100,
0x6f9700, 0x6a5d00, 0x647b00, 0x5dfb00,
0x668800, 0x6ae500, 0x6f1300, 0x72f900,

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0x767f00, 0x799000, 0x7c1a00, 0x7e0b00,
0x7f5700, 0x7ff300, 0x7fd700, 0x7eff00,
0x7d6600, 0x7b0d00, 0x77f500, 0x742100,
0x6f9700, 0x6a5d00, 0x647b00, 0x5dfb00,
0x667e00, 0x6ad800, 0x6f0200, 0x72e300,
0x766500, 0x797200, 0x7bf900, 0x7dec00,
0x7f3e00, 0x7fe900, 0x7fe900, 0x7f3e00,
0x7dec00, 0x7bf900, 0x797200, 0x766500,
0x72e300, 0x6f0200, 0x6ad800, 0x667e00,
0x5c0b00, 0x5eee00, 0x619c00, 0x640a00,
0x662b00, 0x67f800, 0x696d00, 0x6a8600,
0x6b4200, 0x6ba000, 0x6ba000, 0x6b4200,
0x6a8600, 0x696d00, 0x67f800, 0x662b00,
0x640a00, 0x619c00, 0x5eee00, 0x5c0b00,
0x5c0000, 0x5ede00, 0x618600, 0x63eb00,
0x660100, 0x67c000, 0x692200, 0x6a2300,
0x6abf00, 0x6af300, 0x6abc00, 0x6a1500,
0x68fa00, 0x676300, 0x654b00, 0x62a900,
0x5f7800, 0x5bb000, 0x574e00, 0x525000,
0xadd400, 0xa8d900, 0xa47d00, 0xa0be00,
0x9d9700, 0x9b0200, 0x98fc00, 0x977e00,
0x968200, 0x960500, 0x960500, 0x968200,
0x977e00, 0x98fc00, 0x9b0200, 0x9d9700,
0xa0be00, 0xa47d00, 0xa8d900, 0xadd400,
0xadc800, 0xa8c800, 0xa46500, 0xa09d00,
0x9d6a00, 0x9ac800, 0x98af00, 0x971700,
0x95fc00, 0x955400, 0x951e00, 0x955200,
0x95ee00, 0x96ef00, 0x985200, 0x9a1100,
0x9c2800, 0x9e8e00, 0xa13700, 0xa41500,
0xa21a00, 0x9b9800, 0x95b400, 0x907800,
0x8beb00, 0x881500, 0x84fb00, 0x82a000,
0x810500, 0x802a00, 0x800c00, 0x80a600,
0x81f000, 0x83df00, 0x866600, 0x897500,
0x8cfa00, 0x90de00, 0x950a00, 0x996600,
0xa20f00, 0x9b8900, 0x95a000, 0x905f00,
0x8bce00, 0x87f400, 0x84d700, 0x827d00,
0x80e800, 0x801c00, 0x801a00, 0x80e100,
0x827100, 0x84c700, 0x87df00, 0x8bb500,

SUBSTITUTE SHEET (RULE 26)

0x904200, 0x957f00, 0x9b6300, 0xale600;

.INIT initial_I_samples:

0xffff800, 0xffff500, 0xffef00,
0xffe800, 0xffde00, 0xffd100,
0xffbf00, 0xffa700, 0xff8900,
0xff6200, 0xff3000, 0xfef100,
0xfea100, 0xfe3e00, 0xfdc300,
0xfd2c00, 0xfc7400, 0xfb9700,
0xfa8e00, 0xf95400, 0xf7e100,
0xf62f00, 0xf43600, 0xf1f100,
0xef5900, 0xec6900, 0xe91c00,
0xe56e00, 0xe15f00, 0xdcef00,
0xd82100, 0xd2fb00, 0xcd8500,
0xc7cb00, 0xc1db00, 0xbbc400,
0xb59800, 0xaf6c00, 0xa95200,
0xa36000, 0x9dab00, 0x984700,
0x934800, 0x8ebf00, 0x8abc00,
0x874d00, 0x847e00, 0x825800,
0x80e200, 0x802000, 0x801100,
0x80b400, 0x820200, 0x83f300,
0x867a00, 0x898800, 0x8d0b00,
0x90ed00, 0x951700, 0x997100;

.INIT initial_Q_samples:

0x7ffe00, 0x7ffe00, 0x7ffe00,
0x7ffe00, 0x7ffe00, 0x7ffe00,
0x7ffe00, 0x7ffe00, 0x7ffe00,
0x7ffe00, 0x7ffe00, 0x7ffd00,
0x7ffd00, 0x7ffb00, 0x7ff900,
0x7ff600, 0x7ff200, 0x7feb00,
0x7fe100, 0x7fd200, 0x7fbc00,
0x7f9e00, 0x7f7300, 0x7f3800,
0x7ee800, 0x7e7c00, 0x7dee00,
0x7d3500, 0x7c4600, 0x7b1900,
0x79a000, 0x77d100, 0x759e00,
0x72fe00, 0x6fe500, 0x6c4a00,
0x682500, 0x637200, 0x5e2d00,

SUBSTITUTE SHEET (RULE 26)

```

0x585600, 0x51ef00, 0x4aff00,
0x438c00, 0x3ba100, 0x334a00,
0x2a9600, 0x219600, 0x185b00,
0x0ef800, 0x058100, 0xfc0c00,
0xf2ab00, 0xe97400, 0xe07b00,
0xd7d300, 0xcf8d00, 0xc7ba00,
0xc06700, 0xb9a000, 0xb36d00;

```

```
.INIT carrier_I_sample: 0x000000;
```

```
.INIT carrier_Q_sample: 0x7fff00;
```

III. Table for Baseband Modulation

```

/* obj\moddatbb.h: was created using the command line:
 * obj\modtab.exe -b -f -i -oobj\moddatbb.h
 * The data is in the 16 MSB of the 24 bit words, which
 * are used by the DSP when getting data from program
 * memory. */

```

```
.INIT I_samples:
```

```

0x801e00, 0x801600, 0x801100, 0x800d00,
0x800a00, 0x800700, 0x800600, 0x800500,
0x800500, 0x800400, 0x800500, 0x800500,
0x800600, 0x800700, 0x800a00, 0x800d00,
0x801100, 0x801600, 0x801e00, 0x802900,
0x808600, 0x80a400, 0x80d300, 0x811100,
0x816400, 0x81d100, 0x825e00, 0x830f00,
0x83ef00, 0x850400, 0x865b00, 0x87fb00,
0x89ee00, 0x8c4500, 0x8f0800, 0x924300,
0x960500, 0x9a5a00, 0x9f4c00, 0xa4e300,
0xab0e00, 0xb1e800, 0xb96d00, 0xc19300,
0xca5000, 0xd38b00, 0xdd2c00, 0xe71100,
0xf11100, 0xfb0000, 0x04af00, 0x0def00,
0x169400, 0x1e6d00, 0x255800, 0x2b3300,
0x2fdd00, 0x334600, 0x355c00, 0x361700,
0xab7600, 0xb27600, 0xba2f00, 0xc29700,
0xcbaa00, 0xd55500, 0xdf8400, 0xea1b00,
0xf4fb00, 0x000000, 0x0b0500, 0x15e500,
0x207c00, 0x2aab00, 0x345600, 0x3d6900,
0x45d100, 0x4d8a00, 0x548a00, 0x5ad100,
0x355c00, 0x334600, 0x2fdd00, 0x2b3300,

```

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0x255800, 0x1e6d00, 0x169400, 0x0def00,
0x04af00, 0xfb0000, 0xf11100, 0xe71100,
0xdd2c00, 0xd38b00, 0xca5000, 0xc19300,
0xb96d00, 0xb1e800, 0xab0e00, 0xa4e300,
0x35c400, 0x33d400, 0x309f00, 0x2c3700,
0x26b200, 0x203700, 0x18ec00, 0x10f900,
0x089900, 0x000000, 0xf76700, 0xef0700,
0xe71400, 0xdfc900, 0xd94e00, 0xd3c900,
0xcf6100, 0xcc2c00, 0xca3c00, 0xc99d00,
0x604c00, 0x651800, 0x693900, 0x6cb900,
0x6f9e00, 0x71f100, 0x73ba00, 0x74fb00,
0x75bb00, 0x75fc00, 0x75bb00, 0x74fb00,
0x73ba00, 0x71f100, 0x6f9e00, 0x6cb900,
0x693900, 0x651800, 0x604c00, 0x5ad100,
0x60b400, 0x65a600, 0x69fb00, 0x6dbd00,
0x70f800, 0x73bb00, 0x761200, 0x780500,
0x79a500, 0x7afc00, 0x7c1100, 0x7cf100,
0x7da200, 0x7e2f00, 0x7e9c00, 0x7eef00,
0x7f2d00, 0x7f5c00, 0x7f7a00, 0x7f8b00,
0x9f4c00, 0x9a5a00, 0x960500, 0x924300,
0x8f0800, 0x8c4500, 0x89ee00, 0x87fb00,
0x865b00, 0x850400, 0x83ef00, 0x830f00,
0x825e00, 0x81d100, 0x816400, 0x811100,
0x80d300, 0x80a400, 0x808600, 0x807500,
0x9fb400, 0x9ae800, 0x96c700, 0x934700,
0x906200, 0x8e0f00, 0x8c4600, 0x8b0500,
0x8a4500, 0x8a0400, 0x8a4500, 0x8b0500,
0x8c4600, 0x8e0f00, 0x906200, 0x934700,
0x96c700, 0x9ae800, 0x9fb400, 0xa52f00,
0xca3c00, 0xcc2c00, 0xcf6100, 0xd3c900,
0xd94e00, 0xdfc900, 0xe71400, 0xef0700,
0xf76700, 0x000000, 0x089900, 0x10f900,
0x18ec00, 0x203700, 0x26b200, 0x2c3700,
0x309f00, 0x33d400, 0x35c400, 0x366300,
0xcaa400, 0xccba00, 0xd02300, 0xd4cd00,
0xdaa800, 0xe19300, 0xe96c00, 0xf21100,
0xfb5100, 0x050000, 0x0eef00, 0x18ef00,
0x22d400, 0x2c7500, 0x35b000, 0x3e6d00,

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0x469300, 0x4e1800, 0x54f200, 0x5b1d00,
 0x548a00, 0x4d8a00, 0x45d100, 0x3d6900,
 0x345600, 0x2aab00, 0x207c00, 0x15e500,
 0x0b0500, 0x000000, 0xf4fb00, 0xea1b00,
 0xdf8400, 0xd55500, 0xcbaa00, 0xc29700,
 0xba2f00, 0xb27600, 0xab7600, 0xa52f00,
 0x54f200, 0x4e1800, 0x469300, 0x3e6d00,
 0x35b000, 0x2c7500, 0x22d400, 0x18ef00,
 0x0eef00, 0x050000, 0xfb5100, 0xf21100,
 0xe96c00, 0xe19300, 0xdaa800, 0xd4cd00,
 0xd02300, 0xccba00, 0xcaa400, 0xc9e900,
 0x7f7a00, 0x7f5c00, 0x7f2d00, 0x7eef00,
 0x7e9c00, 0x7e2f00, 0x7da200, 0x7cf100,
 0x7c1100, 0x7afc00, 0x79a500, 0x780500,
 0x761200, 0x73bb00, 0x70f800, 0x6dbd00,
 0x69fb00, 0x65a600, 0x60b400, 0x5b1d00,
 0x7fe200, 0x7fea00, 0x7fef00, 0x7ff300,
 0x7ff600, 0x7ff900, 0x7ffa00, 0x7ffb00,
 0x7ffb00, 0x7ffc00, 0x7ffb00, 0x7ffb00,
 0x7ffa00, 0x7ff900, 0x7ff600, 0x7ff300,
 0x7fef00, 0x7fea00, 0x7fe200, 0x7fd700;

.INIT Q_samples:

0x7fe200, 0x7fea00, 0x7fef00, 0x7ff300,
 0x7ff600, 0x7ff900, 0x7ffa00, 0x7ffb00,
 0x7ffb00, 0x7ffc00, 0x7ffb00, 0x7ffb00,
 0x7ffa00, 0x7ff900, 0x7ff600, 0x7ff300,
 0x7fef00, 0x7fea00, 0x7fe200, 0x7fd700,
 0x7f7a00, 0x7f5c00, 0x7f2d00, 0x7eef00,
 0x7e9c00, 0x7e2f00, 0x7da200, 0x7cf100,
 0x7c1100, 0x7afc00, 0x79a500, 0x780500,
 0x761200, 0x73bb00, 0x70f800, 0x6dbd00,
 0x69fb00, 0x65a600, 0x60b400, 0x5b1d00,
 0x54f200, 0x4e1800, 0x469300, 0x3e6d00,
 0x35b000, 0x2c7500, 0x22d400, 0x18ef00,
 0x0eef00, 0x050000, 0xfb5100, 0xf21100,
 0xe96c00, 0xe19300, 0xdaa800, 0xd4cd00,
 0xd02300, 0xccba00, 0xcaa400, 0xc9e900,

SUBSTITUTE SHEET (RULE 26)

0x548a00, 0x4d8a00, 0x45d100, 0x3d6900,
0x345600, 0x2aab00, 0x207c00, 0x15e500,
0x0b0500, 0x000000, 0xf4fb00, 0xea1b00,
0xdf8400, 0xd55500, 0xcbaa00, 0xc29700,
0xba2f00, 0xb27600, 0xab7600, 0xa52f00,
0xcaa400, 0xccba00, 0xd02300, 0xd4cd00,
0xdaa800, 0xe19300, 0xe96c00, 0xf21100,
0xfb5100, 0x050000, 0x0eef00, 0x18ef00,
0x22d400, 0x2c7500, 0x35b000, 0x3e6d00,
0x469300, 0x4e1800, 0x54f200, 0x5b1d00,
0xca3c00, 0xcc2c00, 0xcf6100, 0xd3c900,
0xd94e00, 0xdfc900, 0xe71400, 0xef0700,
0xf76700, 0x000000, 0x089900, 0x10f900,
0x18ec00, 0x203700, 0x26b200, 0x2c3700,
0x309f00, 0x33d400, 0x35c400, 0x366300,
0x9fb400, 0x9ae800, 0x96c700, 0x934700,
0x906200, 0x8e0f00, 0x8c4600, 0x8b0500,
0x8a4500, 0x8a0400, 0x8a4500, 0x8b0500,
0x8c4600, 0x8e0f00, 0x906200, 0x934700,
0x96c700, 0x9ae800, 0x9fb400, 0xa52f00,
0x9f4c00, 0x9a5a00, 0x960500, 0x924300,
0x8f0800, 0x8c4500, 0x89ee00, 0x87fb00,
0x865b00, 0x850400, 0x83ef00, 0x830f00,
0x825e00, 0x81d100, 0x816400, 0x811100,
0x80d300, 0x80a400, 0x808600, 0x807500,
0x60b400, 0x65a600, 0x69fb00, 0x6dbd00,
0x70f800, 0x73bb00, 0x761200, 0x780500,
0x79a500, 0x7afc00, 0x7c1100, 0x7cf100,
0x7da200, 0x7e2f00, 0x7e9c00, 0x7eef00,
0x7f2d00, 0x7f5c00, 0x7f7a00, 0x7f8b00,
0x604c00, 0x651800, 0x693900, 0x6cb900,
0x6f9e00, 0x71f100, 0x73ba00, 0x74fb00,
0x75bb00, 0x75fc00, 0x75bb00, 0x74fb00,
0x73ba00, 0x71f100, 0x6f9e00, 0x6cb900,
0x693900, 0x651800, 0x604c00, 0x5ad100,
0x35c400, 0x33d400, 0x309f00, 0x2c3700,
0x26b200, 0x203700, 0x18ec00, 0x10f900,
0x089900, 0x000000, 0xf76700, 0xef0700,

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```

0xe71400, 0xdfc900, 0xd94e00, 0xd3c900,
0xcf6100, 0xcc2c00, 0xca3c00, 0xc99d00,
0x355c00, 0x334600, 0x2fdd00, 0x2b3300,
0x255800, 0x1e6d00, 0x169400, 0x0def00,
0x04af00, 0xfb0000, 0xf11100, 0xe71100,
0xdd2c00, 0xd38b00, 0xca5000, 0xc19300,
0xb96d00, 0xb1e800, 0xab0e00, 0xa4e300,
0xab7600, 0xb27600, 0xba2f00, 0xc29700,
0xcbaa00, 0xd55500, 0xdf8400, 0xea1b00,
0xf4fb00, 0x000000, 0x0b0500, 0x15e500,
0x207c00, 0x2aab00, 0x345600, 0x3d6900,
0x45d100, 0x4d8a00, 0x548a00, 0x5ad100,
0xab0e00, 0xb1e800, 0xb96d00, 0xc19300,
0xca5000, 0xd38b00, 0xdd2c00, 0xe71100,
0xf11100, 0xfb0000, 0x04af00, 0x0def00,
0x169400, 0x1e6d00, 0x255800, 0x2b3300,
0x2fdd00, 0x334600, 0x355c00, 0x361700,
0x808600, 0x80a400, 0x80d300, 0x811100,
0x816400, 0x81d100, 0x825e00, 0x830f00,
0x83ef00, 0x850400, 0x865b00, 0x87fb00,
0x89ee00, 0x8c4500, 0x8f0800, 0x924300,
0x960500, 0x9a5a00, 0x9f4c00, 0xa4e300,
0x801e00, 0x801600, 0x801100, 0x800d00,
0x800a00, 0x800700, 0x800600, 0x800500,
0x800500, 0x800400, 0x800500, 0x800500,
0x800600, 0x800700, 0x800a00, 0x800d00,
0x801100, 0x801600, 0x801e00, 0x802900;

```

.INIT initial_I_samples:

```

0xffcc00, 0xffb900, 0xff9f00,
0xff7e00, 0xff5300, 0xff1b00,
0xfed400, 0xfe7b00, 0xfe0b00,
0xfd8000, 0xfcd400, 0xfc0300,
0xfb0900, 0xf9dd00, 0xf87b00,
0xf6dc00, 0xf4f900, 0xf2cb00,
0xf04e00, 0xed7d00, 0xea5400,
0xe6d000, 0xe2f100, 0xdebb00,
0xda3000, 0xd55900, 0xd04100,

```

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0xcaf500, 0xc58500, 0xc00200,
0xba8100, 0xb51200, 0xafc800,
0xaab200, 0xa5e000, 0xa15b00,
0x9d2d00, 0x995900, 0x95e500,
0x92d200, 0x901d00, 0x8dc600,
0x8bcd00, 0x8a2c00, 0x88e300,
0x87f000, 0x875200, 0x870a00,
0x871a00, 0x878400, 0x885100,
0x898200, 0x8b1d00, 0x8d2e00,
0x8fbb00, 0x92ce00, 0x967300,
0x9ab400, 0x9f9b00, 0xa52f00;

.INIT initial_Q_samples:

0x003400, 0x004700, 0x006100,
0x008200, 0x00ad00, 0x00e500,
0x012c00, 0x018500, 0x01f500,
0x028000, 0x032c00, 0x03fd00,
0x04f700, 0x062300, 0x078500,
0x092400, 0x0b0700, 0x0d3500,
0x0fb200, 0x128300, 0x15ac00,
0x193000, 0x1d0f00, 0x214500,
0x25d000, 0x2aa700, 0x2fbf00,
0x350b00, 0x3a7b00, 0x3ffe00,
0x457f00, 0x4aee00, 0x503800,
0x554e00, 0x5a2000, 0x5ea500,
0x62d300, 0x66a700, 0x6a1b00,
0x6d2e00, 0x6fe300, 0x723a00,
0x743300, 0x75d400, 0x771d00,
0x781000, 0x78ae00, 0x78f600,
0x78e600, 0x787c00, 0x77af00,
0x767e00, 0x74e300, 0x72d200,
0x704500, 0x6d3200, 0x698d00,
0x654c00, 0x606500, 0x5ad100;

.INIT carrier_I_sample: 0x000000;

.INIT carrier_Q_sample: 0x000000;

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APPENDIX B

MODULATION/DEMODULATION AND COMMUNICATIONS PROTOCOL SOFTWARE

I. Receive Code

```

MODULE/RAM                                decode;
#include "dsp.h"
#include "dspcmd.h"
#include "hip.h"
.ENTRY                                     start_decode;
.ENTRY                                     find_next_head;
.EXTERNAL                                 get_filtered_sample;
.EXTERNAL                                 adjust_sampling_and_read_rssi;
.EXTERNAL                                 init_filter;
.EXTERNAL                                 start_slot_timer;
.EXTERNAL                                 queue_signal;
.GLOBAL                                  network_id;
.VAR/DM/CIRC                             bitsync_buff[12+1];
.INIT                                     bitsync_buff: 0x2000, 0x2000, 0x2000,
0x2000, 0x2000, 0x2000, 0x2000,                                0x2000,
0x2000, 0x2000, 0x2000, 0x2000, 0x2000;
.VAR/DM                                   rssi_save;
.CONST                                  NOISE_DECAY    = 31130; /* 0.95 */
.CONST                                  DC_DECAY       = 32162; /* 0.9815 */
.CONST                                  DC_PASTWEIGHT = -2416; /* 1/12 * 1.106 *
-0.8 */
.CONST                                  DC_NEWWEIGHT  = 3020; /* 1/12 * 1.106 */
.VAR/DM                                   network_id;
.INIT                                   network_id: 0xc4d7;
.VAR/PM/RAM/CIRC                         single_bits[16];
:INIT                                   single_bits: 0x800000, 0x400000,
0x200000, 0x100000, 0x080000, 0x040000, 0x020000, 0x010000,
0x008000, 0x004000, 0x002000, 0x001000,
0x000800, 0x000400, 0x000200, 0x000100;
.VAR/DM                                   DC_Level;
.PORT                                   debug_out;
start_decode:
    call init_filter; ay1 = 0x2000;
    dm(DC_Level) = ay1;

```

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```

find_next_head:
    ay1 = dm(DC_Level); mx1 = ay1; ax1 = 0;
    i5 = ^bitsync_buff; l5 = 12+1;
    m5 = 0;
sync_search:
    call get_filtered_sample;
    dm(debug_out) = mrl; dm(i5,m4) = mrl;
    ay0 = mx1; ar = mrl-ay0, mx1 = mrl;
    my0 = ar; mr = ar*my0 (ss), mx0 = ax1;
my0 = NOISE_DECAY; mr = mr + mx0*my0 (ss);                                ax1
= mrl;

    /* ax1 now contains updated noise index */
    /* now update the DC level readings */
my0 = DC_NEWWEIGHT;
    mr = mx1 * my0 (ss), mx0 = ay1; my0 = DC_DECAY;
    mr = mr + mx0 * my0 (ss), mx0 = dm(i5,m5);
    my0 = DC_PASTWEIGHT;
    mr = mr + mx0 * my0 (rnd);
    dm(debug_out) = ay1;
    ay0 = 550;
    ar = ax1 - ay0, ay1 = mrl;
    if lt jump sync_search;
    ay0 = 1600; ar = ax1 - ay0;
    if gt jump sync_search;
    ax0 = 700;
    af = ax0 + ay1, ax0 = dm(i5,m5);
    ar = af - ax0, ax0 = mx1;
    if gt jump sync_search;
    ar = af - ax0;
    if gt jump sync_search;
    /* now correlate to 2 khz sine wave to get data for
next criteria */
    /* use AR and AF to feed stuff back.*/
    ar = pass 0; cntr = 3;
    ay0 = dm(i5,m4), af = pass 0; /* m1 is 1 */
    do sin_loop until ce;
        ar = ar + ay0, ax0 = dm(i5,m4);
        af = ax0 + af, ay0 = dm(i5,m4);

```

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```

        ar = ar - ay0, ax0 = dm(i5,m4);
sin_loop:  af = af - ax0, ay0 = dm(i5,m4);
        /* ar and af now contain sin and cos components 5
should be what it was before the loopmake sure af < ar */
        ax0 = ar, ar = ar - af;
        if lt jump sync_search;
        ar = ax0 + af, my1 = ax0;
        ar = ar + 512;
        if lt jump sync_search;
        mx0 = ax0, ar = pass af;
        mr = mx0 * my1 (ss), my0 = ar;
        mr = mr + ar * my0 (ss);
        ay0 = 1700;
        ar = mr1 - ay0;                /* threshold */
        /* make sure sinusoidal component is of a certain size
at least */
        if lt jump sync_search;
        ay0 = 0;  ar = pass ax0;
        /* dividend is in af:ay0, which contains original
sin_loop af result */
        /* divisor is in sr0 , which contains original
sin_loop ar result */
        divs af, ar;  cntr = 15;
        do div_loop until ce;
div_loop:  divq ar;
        /* the result of this is in ay0 and can span the full
range of a signed */
        /* integer. now use this value to compute the
adjustment */
        /* Adjustment = S * 1.243 + s^3 * -0.25 */
        /* scale times 768 */
        mx0 = ay0;
        my0 = 955; /* linear scale factor */
        mr = mx0 * my0 (ss), my0 = mx0;
        mf = mx0 * my0 (rnd); mf = mx0 * mf (rnd);
        mx0 = -192; /* cubic scale factor */
        mr = mr + mx0 * mf (rnd);

```

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```

/* Result: between -768 and 768 in mrl (thanks to 1.15
arithmetic) each increment of 256 is one sample's worth.now
add an arbitrary value for tweaking. */
    ay0 = 712; ar = mrl + ay0;
    dm(debug_out) = ar; dm(debug_out) = ar;
/* now divide by 256 to calculate actual number of
samples to adjust */
    sr = ashift ar by -8 (lo);
/* result is in the range of -6 to +6 in sr0 */
    call adjust_sampling_and_read_rssi;
/* ay0 now contains the raw rssi value. */
    dm(rssi_save) = ay0;
/* Bit sync is completed and RSSI is read. set up for bit
decoding */
set_levels: /* next: Set the trigger levels */
.VAR/DM/RAM      Threshold_Last_1;
.VAR/DM/RAM      Threshold_Last_0;
.VAR/DM/RAM      Threshold_Next_Bit;
    ax0 = 200; dm(DC_Level) = ay1; ar = ax0 + ay1;
    dm(Threshold_Last_1) = ar; ar = ay1 - ax0;
    dm(Threshold_Last_0) = ar;
    dm(Threshold_Next_Bit) = ay1;
/* Now search for frame sync. initialize initial frame sync to
all 1's. Canadian and us frame syncs start with a 1, so this
improves our chance of getting it if we were late by one bit
on catching it! */
    sr0 = 0xffff; /* search for frame sync for 24 bit
times */
    cntr = 24; do fsync_search until ce;
    cntr = 1; all get_n_bits_data; /*
uses: AY1, AX1, AF, SR, SI, CNTR */
    ay0 = DM(network_id);
    ar = sr0 xor ay0; ax0 = ar;
    i4 = ^single_bits;
    ay0 = pm(i4,m4), af = pass 0;
    cntr = 16;
    do count_errors until ce;
    ar = ax0 and ay0, ay0 = pm(i4,m4);

```

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```

count_errors:  if ne af = af + 1;
                /* AF now contains number of mismatches */
                af = af - 1;
                if le jump found_frame_sync;
fsync_search:nop; /* end of loop */
                jump find_next_head;
found_frame_sync:
                /* pop stack of unfinished loop */
                pop pc, pop cntr, pop loop;
/* Found frame sync.  Now decode data.          */
                /* get first 8 bits of first word */
                sr0 = 0;
                call get_8_bits_data;
                mx1 = sr0; /* get first 8 bits of second word */
                sr0 = 0; call get_8_bits_data; my1 = sr0;
                /* get remaining 4 bits of first word */
                cntr = 4;
                sr0 = 0;
                call get_n_bits_data;
                /* build first 12 bit word */
                sr = lshift sr0 by 8(10);
                ay0 = mx1;
                ar = sr0 or ay0;
                /* fec correct and store resulting 8 bit word */
                ax0 = ar; call fec_correct;  mx1 = ar;
                /* get remaining 4 bits of second word */
                cntr = 4;  sr0 = 0; call get_n_bits_data;
                /* build second 12 bit word */
                sr = lshift sr0 by 8 (10);
                ay0 = my1;  ar = sr0 or ay0;  ax0 = ar;
                call fec_correct;
                /* put frame head data into hip */
                dm(hip_data0) = mx1; dm(hip_data1) = ar;
                ax0 = dm(rssi_save);  dm(hip_data2) = ax0;
                /* check if silence of slot clock bits are set */
                ay0 = 0x0003;
                af = ar and ay0;
                if eq jump more_data_follows;

```

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```

        /* signal host head only is received */
        ax0 = RECEIVED_FRAME_HEAD_ONLY;
        call queue_signal;
        jump find_next_head;
more_data_follows:
        /* signal host that head with data is received */
        ax0 = RECEIVED_FRAME_HEAD;
        call queue_signal;
        /* check for slot clock reset bit */
        ar = ar and 4;
        if ne call start_slot_timer;
shovel_data:
        call get_8_bits_data;    mx1 = sr0;
        call get_8_bits_data;    my1 = sr0;
        call get_8_bits_data; dm(hip_data0) = mx1;
        dm(hip_data1) = my1; dm(hip_data2) = sr0;
        ax0 = RECEIVED_3_BYTES;
        call queue_signal;
        jump shovel_data;
.VAR/DM/RAM    sr0_save;
get_8_bits_data:
        cntr = 8;
get_n_bits_data:
        ayl = dm(Threshold_Next_Bit);
        do get_bits until CE;
            dm(sr0_save) = sr0;
            call get_filtered_sample; /* result in mr1 */
            sr0 = dm(sr0_save);
            dm(debug_out) = mr1; dm(debug_out) = mr1;
            af = mr1 - ayl;
            if lt jump iszero2;
                si = 1;
                ayl = dm(Threshold_Last_1);
                jump endif_getn;
iszero2:
        si = 0;
        /* set threshold for previoys bit 0 */
        ayl = dm(Threshold_Last_0);

```

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```

        /* RESET FL2; */
    endif_getn:
        sr = lshift sr0 by 1 (LO);
get_bits:
        sr = sr or lshift si by 0 (lo);
        dm(Threshold_Next_Bit) = AY1;
        rts;

.VAR/PM/RAM    fec_masks[12];
.INIT          fec_masks: 0x08EC00, 0x04D300, 0x02BA00,
0x017500;

.VAR/PM/RAM    fec_syndrome_fix[16];
.INIT          fec_syndrome_fix:
0x000000,0x000000,0x000000,0x00ff00,0x000000,0x000100,0x000200
,0x001000,0x000400,0x000800,0x002000,0x00ff00,0x004000,0x00800
0,0x00ff00;
fec_correct:
        l4 = 0; l5 = 0; m4 = 1;
        i5 = ^fec_masks; si = 1;
        /* shifter setup for creating syndrome */
        se = 0; ay1 = 0; sr0 = 0; cntr = 4;
        do andlp until ce;
            ay0 = pm(i5,m4); ar = ax0 and ay0;
        ax1 = ar, af = ax0 and ay1;
        cntr = 12; i4 = ^single_bits+4;
set up for going through bit table */
        ay0 = pm(i4,m4);
        do count_loop until ce;
            ar = ax1 and ay0, ay0 = pm(i4,m4);
count_loop:    if ne af = af + 1; sr = lshift sr0 by 1 (lo);
ax1 = 1; af = ax1 and af;
andlp:    if ne sr = sr or lshift si (lo);
        m4 = sr0;
        i5 = ^fec_syndrome_fix;
        modify (i5,m4);
        ay0 = pm(i5,m4);
        ar = ax0 xor ay0;

```

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```

    rts;
.ENDMOD;

```

II. Transmission Code

```

// DSP Transmit code
.MODULE/RAM transmit_code;
#include "dsp.h"
#include "dspcmd.h";
#include "hip.h"

#define TX_ZERO_SAMPLES
.EXTERNAL process_dsp_command;
.EXTERNAL wait_for_dsp_command;
.EXTERNAL queue_signal;
.ENTRY initialize_transmit;
.ENTRY process_transmit_command;
.ENTRY SPORT0_tx_interrupt;
.CONST POSITIVE_ONE = 0x7FFF;
.CONST POSITIVE_HALF = 0x4000;
.CONST NEGATIVE_ONE = 0x8001;
.CONST ZERO = 0x0000;
.CONST TRUE = 0x1;
.CONST FALSE = 0x0;
.CONST INITIAL_BIT_HISTORY = 0x0033;
.CONST INITIAL_BIT_SHIFT = 0x0003;
.CONST INITIAL_PHASE = 0x0001;
.CONST OLDEST_BIT = 3;
#ifdef LARGE_DATA_BUFFER
.CONST DATA_BUFFER_LENGTH = 1000;
#else
.CONST DATA_BUFFER_LENGTH = 9;
#endif
.CONST NUM_PENDING_BITS_THRESHOLD = (DATA_BUFFER_LENGTH - 6) *
8;
.CONST OVERSAMPLING = 20;
.CONST INITIAL_MIN_CARRIER_SAMPLES = OVERSAMPLING * 8 * 5 +
(OVERSAMPLING * 8 * 2);
.CONST SERIAL0_ENABLE_BIT = 12;

```

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```

.VAR/DM tx_scale_factor;
.VAR/DM tx_I_scale_factor;
.VAR/DM tx_I_phase_factor;
.VAR/DM tx_I_offset;
.VAR/DM tx_Q_phase_factor;
.VAR/DM tx_Q_offset;
.VAR/DM tx_I_sign;
.VAR/DM tx_Q_sign;
.VAR/DM tx_next_I_sign;
.VAR/DM tx_next_Q_sign;
.VAR/DM tx_num_samples;
.VAR/DM tx_next_num_samples;
.VAR/DM use_num_pending_bits_threshold;    { copy of
NUM_PENDING_BITS_THRESHOLD or 0 }
.VAR/DM tx_next_I_sample_ptr;
.VAR/DM tx_next_I_sample_length;
.VAR/DM tx_next_Q_sample_ptr;
.VAR/DM tx_next_Q_sample_length;
.VAR/DM tx_ready_for_more_samples_flag;
.VAR/DM tx_next_Q_sample;
.VAR/DM tx_I_sample_flag;
.VAR/DM tx_num_bits_in_sr0;
.VAR/DM tx_num_pending_bits;
.VAR/DM tx_phase;
.VAR/DM tx_received_data_flag;
.VAR/DM tx_min_carrier_samples;
.VAR/DM/CIRC data_buffer[ DATA_BUFFER_LENGTH ];
.VAR/PM/CIRC carrier_I_sample;
.VAR/PM/CIRC carrier_Q_sample;
.VAR/PM initial_I_samples[ 3 * OVERSAMPLING ];
.VAR/PM initial_Q_samples[ 3 * OVERSAMPLING ];
.VAR/PM I_samples[ 16 * OVERSAMPLING ];
.VAR/PM Q_samples[ 16 * OVERSAMPLING ];
.VAR/PM phase_data[ 4 * 4 ];
#ifdef BASEBAND
#include "obj\moddatiq.h"
.INIT phase_data: ^I_samples, ^Q_samples, 0x7fff00, 0x7fff00,
/* 0 */

```

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```

        ^Q_samples, ^I_samples, 0x7fff00, 0x800100,
/* 1 */
        ^I_samples, ^Q_samples, 0x800100, 0x800100,
/* 2 */
        ^Q_samples, ^I_samples, 0x800100, 0x7fff00;
/* 3 */
#else
#include "obj\moddatbb.h"
.INIT phase_data: ^I_samples, ^Q_samples, 0x7fff00, 0x7fff00,
/* 0 */
        ^I_samples, ^Q_samples, 0x7fff00, 0x7fff00,
/* 0 */
        ^I_samples, ^Q_samples, 0x7fff00, 0x7fff00,
/* 0 */
        ^I_samples, ^Q_samples, 0x7fff00, 0x7fff00;
/* 0 */
#endif
#ifdef TX_ZERO_SAMPLES
.VAR/PM/CIRC zero_sample;
.INIT zero_sample: 0x000000;
#endif
.CONST FIRST_TRANSMIT_COMMAND = 0x10;
.CONST NUM_TRANSMIT_COMMANDS = 12;
.VAR/PM transmit_jump_table[ NUM_TRANSMIT_COMMANDS ];
.INIT transmit_jump_table:
    ^process_transmit_scale_factor,
    ^process_transmit_I_scale_factor,
    ^process_transmit_Q_phase_factor,
    ^process_transmit_I_offset,
    ^process_transmit_Q_offset,
    ^process_transmit_min_carrier_samples,
    ^process_transmit_start_carrier,
    ^save_one_byte,
    ^save_two_bytes,
    ^save_three_bytes,
    ^process_transmit_complete_command,
    ^wait_for_transmit_command;

```

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initialize_transmit:

```

    ax0 = INITIAL_MIN_CARRIER_SAMPLES;
    dm( tx_min_carrier_samples ) = ax0;
    m7 = 0; /* initialize dummy variables */
    l7 = 0;
    rts;

```

process_transmit_command:

```

    ena m_mode;
    call initialize_transmit_variables;
    jump check_for_valid_tx_command;
    wait_for_transmit_command:
        idle;
        ax0 = dm( tx_ready_for_more_samples_flag );
        ay0 = dm( tx_received_data_flag );
        ar = ax0 and ay0;
        if ne jump calculate_next_bit_samples;
        ax0 = dm( HSR6_SHADOW );
        ar = tstbit HSR_DSP_COMMAND_BIT of ax0;
        if eq jump wait_for_transmit_command;

```

check_for_valid_tx_command:

```

    ax0 = 0x0;
    dm( HSR6_SHADOW ) = ax0;
    ax0 = dm( HIP_DSP_COMMAND_SHADOW );
    ay0 = FIRST_TRANSMIT_COMMAND;
    af = ax0 - ay0;
    if lt jump transmit_stop;
    ax0 = NUM_TRANSMIT_COMMANDS;
    ar = ax0 - af;
    if gt jump process_tx_command;

```

transmit_stop:

```

    call stop_serial_port;
    jump process_dsp_command;

```

process_tx_command:

```

    ax0 = ^transmit_jump_table;

```

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```
ar = ax0 + af;
i7 = ar;
ax0 = pm( i7, m7 );
i7 = ax0;
jump (i7);
```

```
process_transmit_scale_factor:
    call get_word_from_HIP;
    DM( tx_scale_factor ) = mr0;
    jump wait_for_transmit_command;
```

```
process_transmit_I_scale_factor:
    call get_word_from_HIP;
    DM( tx_I_scale_factor ) = mr0;
    jump wait_for_transmit_command;
```

```
process_transmit_I_offset:
    call get_word_from_HIP;
    dm( tx_I_offset ) = mr0;
    jump wait_for_transmit_command;
```

```
process_transmit_Q_phase_factor:
    call get_word_from_HIP;
    dm( tx_Q_phase_factor ) = mr0;
    af = abs mr0;
    ax0 = POSITIVE_ONE;
    ar = ax0 - af;
    dm( tx_I_phase_factor ) = ar;
    jump wait_for_transmit_command;
```

```
process_transmit_Q_offset:
    call get_word_from_HIP;
    dm( tx_Q_offset ) = mr0;
    jump wait_for_transmit_command;
```

```
process_transmit_min_carrier_samples:
    call get_word_from_HIP;
    dm( tx_min_carrier_samples ) = mr0;
```

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```
jump wait_for_transmit_command;
```

```
get_word_from_HIP:
```

```
mx0 = dm( HIP_DATA0_SHADOW );
my0 = 0x0100;
mr = mx0 * my0 (UU);
mx0 = dm( HIP_DATA1_SHADOW );
my0 = 0x0001;
mr = mr + mx0 * my0 (UU);
rts;
```

```
save_three_bytes:
```

```
ax0 = dm( HIP_DATA2_SHADOW );
dm( i0, m0 ) = ax0;
call increment_num_pending_bits_by_8;
```

```
save_two_bytes:
```

```
ax0 = dm( HIP_DATA1_SHADOW );
dm( i0, m0 ) = ax0;
call increment_num_pending_bits_by_8;
```

```
save_one_byte:
```

```
ax0 = dm( HIP_DATA0_SHADOW );
dm( i0, m0 ) = ax0;
call increment_num_pending_bits_by_8;
```

```
ax0 = dm( tx_received_data_flag );
ar = pass ax0;
if eq call setup_bitsync_samples;
ax0 = NUM_PENDING_BITS_THRESHOLD;
dm( use_num_pending_bits_threshold ) = ax0;
call transmit_ready_for_data;
jump wait_for_transmit_command;
```

```
increment_num_pending_bits_by_8:
```

```
ax0 = dm( tx_num_pending_bits );
ar = ax0 + 8;
dm( tx_num_pending_bits ) = ar;
```

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rts;

setup_bitsync_samples:

```

ax0 = dm( tx_num_samples );
ar = ax0 + 4;
dm( tx_num_samples ) = ar;
ax0 = ^initial_I_samples;
dm( tx_next_I_sample_ptr ) = ax0;
ax0 = ^initial_Q_samples;
dm( tx_next_Q_sample_ptr ) = ax0;
ax0 = %initial_I_samples;
dm( tx_next_num_samples ) = ax0;
ax0 = 0;
dm( tx_next_I_sample_length ) = ax0;
dm( tx_next_Q_sample_length ) = ax0;
ax0 = POSITIVE_ONE;
dm( tx_next_I_sign ) = ax0;
dm( tx_next_Q_sign ) = ax0;
si = INITIAL_BIT_HISTORY;
sr = lshift si by INITIAL_BIT_SHIFT + 8 (LO);
ax0 = 0x8 - INITIAL_BIT_SHIFT;
dm( tx_num_bits_in_sr0 ) = ax0;
ax0 = INITIAL_PHASE;
dm( tx_phase ) = ax0;
ax0 = TRUE;
dm( tx_received_data_flag ) = ax0;
ax0 = FALSE;
dm( tx_ready_for_more_samples_flag ) = ax0;
rts;

```

process_transmit_complete_command:

```

ax0 = dm( HIP_DATA1_SHADOW );
dm( i0, m0 ) = ax0;
ax0 = dm( tx_num_pending_bits );
ay0 = dm( HIP_DATA0_SHADOW );
ar = ax0 + ay0;
dm( tx_num_pending_bits ) = ar;
ax0 = 0;

```

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```
dm(use_num_pending_bits_threshold) = ax0;
jump wait_for_transmit_command;

process_transmit_start_carrier:
    call stop_serial_port;
    call initialize_transmit_variables;
    i4 = ^carrier_I_sample;
    l4 = %carrier_I_sample;
    i5 = ^carrier_Q_sample;
    l5 = %carrier_Q_sample;
    m4 = 0x1;
    ax0 = ^carrier_I_sample;
    dm( tx_next_I_sample_ptr ) = ax0;
    ax0 = ^carrier_Q_sample;
    dm( tx_next_Q_sample_ptr ) = ax0;

    ax0 = %carrier_I_sample;
    dm( tx_next_I_sample_length ) = ax0;
    dm( tx_next_Q_sample_length ) = ax0;
    ax0 = dm( tx_min_carrier_samples );
    dm( tx_num_samples ) = ax0;
    ax0 = OVERSAMPLING;
    dm( tx_next_num_samples ) = ax0;
    ax0 = POSITIVE_ONE;
    dm( tx_I_sign ) = ax0;
    dm( tx_Q_sign ) = ax0;
    dm( tx_next_I_sign ) = ax0;
    dm( tx_next_Q_sign ) = ax0;
    ax0 = TRUE;
    dm( tx_I_sample_flag ) = ax0;
    ax0 = FALSE;
    dm( tx_ready_for_more_samples_flag ) = ax0;
    ax0 = NUM_PENDING_BITS_THRESHOLD;
    dm( use_num_pending_bits_threshold ) = ax0;
    ax0 = 1 - 1;
    dm( SPORT0_CLOCK_MODULUS ) = ax0;
    ax0 = 30 - 1;
    dm( SPORT0_RX_FS_MODULUS ) = ax0;
```

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```
ax0 = 0x7dcf;
dm( SPORT0_CONTROL ) = ax0;
ax0 = dm( SYSTEM_CONTROL );
ar = setbit SERIAL0_ENABLE_BIT of ax0;
dm( SYSTEM_CONTROL ) = ar;
ax0 = 0x0;
tx0 = ax0;
reset FL1;
nop;
set FL1;
call transmit_ready_for_data;
jump wait_for_transmit_command;
```

transmit_ready_for_data:

```
ax0 = dm( use_num_pending_bits_threshold );
ay0 = dm( tx_num_pending_bits );
ar = ax0 - ay0;
if le rts;
ax0 = TRANSMIT_READY_FOR_DATA;
call queue_signal;
ax0 = 0;
dm( use_num_pending_bits_threshold ) = ax0;
rts;
```

initialize_transmit_variables:

```
i0 = ^data_buffer;
l0 = %data_buffer;
i1 = ^data_buffer;
l1 = %data_buffer;
m0 = 0x1;
ax0 = 0x0000;
dm( tx_ready_for_more_samples_flag ) = ax0;
dm( tx_received_data_flag ) = ax0;
dm( tx_num_pending_bits ) = ax0;
rts;
```

calculate_next_bit_samples:

```
ar = tstbit OLDEST_BIT of srl;
```

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```

ar = 1;
if eq ar = - ar;
ay1 = dm( tx_phase );
ar = ar + ay1;
ay0 = 0x3;
ar = ar and ay0;
dm( tx_phase ) = ar;
ax0 = dm( tx_num_bits_in_sr0 );
ar = pass ax0;
if ne jump shift_bits;
ax1 = dm( tx_num_pending_bits );
ar = pass ax1;
if le jump transmit_completed;
si = dm( il, m0 );
sr = sr or lshift si by 8 (LO);
ay0 = 0x8;
ar = ax1 - ay0;
if ge jump adjust_bit_counts;
ay0 = ax1;

```

```

adjust_bit_counts:
    dm( tx_num_bits_in_sr0 ) = ay0;
    ar = ax1 - ay0;
    dm( tx_num_pending_bits ) = ar;

```

```

shift_bits:
    si = sr0;
    sr = lshift srl by 1 (HI);
    sr = sr or lshift si by 1 (LO);
    ay0 = dm( tx_num_bits_in_sr0 );
    ar = ay0 - 1;
    dm( tx_num_bits_in_sr0 ) = ar;
    ay0 = 0xf;
    ar = srl and ay0;
    my0 = OVERSAMPLING;
    mr = ar * my0 (UU);
    ax1 = mr0;
    mx0 = dm( tx_phase );

```

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```

my0 = 4;
mr = mx0 * my0 (UU);
ay0 = ^phase_data;
ar = mr0 + ay0;
i7 = ar;
ay0 = pm( i7, m4 );
ar = ax1 + ay0;
dm( tx_next_I_sample_ptr ) = ar;
ay0 = pm( i7, m4 );
ar = ax1 + ay0;
dm( tx_next_Q_sample_ptr ) = ar;
ay0 = pm( i7, m4 );
dm( tx_next_I_sign ) = ay0;
ay0 = pm( i7, m4 );
dm( tx_next_Q_sign ) = ay0;
/* set lengths
*
* NOTE: circular buffers must be aligned on address
* boundaries of 2^n words where n is the number of
* bits required to represent the buffer length.
* I.E. for lenght 15 align on 16 word boundries.
* OTHERWISE: set lenght registers to zero, consider
* the buffer as linear and there is no need to align data.
*/
ax0 = OVERSAMPLING;
dm( tx_next_num_samples ) = ax0;
ax0 = 0;
dm( tx_next_I_sample_length ) = ax0;
dm( tx_next_Q_sample_length ) = ax0;
. ax0 = FALSE;
dm( tx_ready_for_more_samples_flag ) = ax0;
jump wait_for_transmit_command;

transmit_completed:
#ifdef TX_ZERO_SAMPLES
ax0 = ^zero_sample;
dm( tx_next_I_sample_ptr ) = ax0;
dm( tx_next_Q_sample_ptr ) = ax0;

```

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```

    ax0 = %zero_sample;
    dm( tx_next_I_sample_length ) = ax0;
    dm( tx_next_Q_sample_length ) = ax0;
    ax0 = 2;
    dm( tx_next_num_samples ) = ax0;
    ax0 = POSITIVE_ONE;
    dm( tx_next_I_sign ) = ax0;
    dm( tx_next_Q_sign ) = ax0;
    ax0 = FALSE;
    dm( tx_ready_for_more_samples_flag ) = ax0;

wait_for_ready_for_more_samples1:
    idle;
    ax0 = dm( tx_ready_for_more_samples_flag );
    ar = pass ax0;
    if eq jump wait_for_ready_for_more_samples1;
    ax0 = FALSE;
    dm( tx_ready_for_more_samples_flag ) = ax0;

wait_for_ready_for_more_samples2:
    idle;
    ax0 = dm( tx_ready_for_more_samples_flag );
    ar = pass ax0;
    if eq jump wait_for_ready_for_more_samples2;
#endif
    ax0 = TRANSMIT_COMPLETED;
    call queue_signal;
    call stop_serial_port;
    jump wait_for_dsp_command;

stop_serial_port:
    ax0 = dm( SYSTEM_CONTROL );
    ar = clrbit SERIAL0_ENABLE_BIT of ax0;
    dm( SYSTEM_CONTROL ) = ar;
    AX0 = 0x0000;
    DM( SPORT0_CONTROL )=AX0;
    rts;

```

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SPORT0_tx_interrupt:

```

    ena sec_reg, dis m_mode, ena ar_sat;
    /* transmit I or Q bit?
    ax0 = dm( tx_I_sample_flag );
    ar = pass ax0;
    if eq jump transmit_Q_sample;

```

transmit_I_sample:

```

    mx0 = pm( i5, m4 );
    my0 = dm( tx_Q_sign );
    mx1 = dm( tx_scale_factor );
    ay0 = dm( tx_Q_offset );
    mf = mx0 * my0 (SS);
    mr = mx1 * mf (SS);
    if mv sat mr;
    ar = mrl + ay0;
    dm( tx_next_Q_sample ) = ar;
    my1 = dm( tx_Q_phase_factor );
    mr = mrl * my1 (SS);
    mx0 = pm( i4, m4 );
    my0 = dm( tx_I_sign );
    ay0 = dm( tx_I_offset );
    mf = mx0 * my0 (SS);
    mf = mx1 * mf (SS);
    mx0 = dm( tx_I_phase_factor );
    mr = mr + mx0 * mf (SS);
    my0 = dm( tx_I_scale_factor );
    mr = mrl * my0 (SS);
    my0 = mrl;
    mx0 = POSITIVE_ONE;
    mr = mr + mx0 * my0 (SS); /*
is 0 to 2 mapped onto 0 to 1) */ * 2 (since I_scale
    if mv sat mr;
    ar = mrl + ay0;
    tx0 = ar;
    ax0 = FALSE;
    DM( tx_I_sample_flag ) = ax0;
    rti;

```

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```

transmit_Q_sample:
    ax0 = DM( tx_next_Q_sample );
    tx0 = ax0;
    ax0 = TRUE;
    DM( tx_I_sample_flag ) = ax0;

/*
 * decrement number of samples left to be played
 */
ay0 = DM( tx_num_samples );
ar = ay0 - 1;
DM( tx_num_samples ) = ar;
/* if more samples then rti
if ne rti;
/* get next set of samples
i4 = dm( tx_next_I_sample_ptr );
l4 = dm( tx_next_I_sample_length );
i5 = dm( tx_next_Q_sample_ptr );
l5 = dm( tx_next_Q_sample_length );
ax0 = DM( tx_next_num_samples );
DM( tx_num_samples ) = ax0;
ax0 = dm( tx_next_I_sign );
dm( tx_I_sign ) = ax0;
ax0 = dm( tx_next_Q_sign );
dm( tx_Q_sign ) = ax0;
// start mainline processing next bit
ax0 = TRUE;
DM( tx_ready_for_more_samples_flag ) = ax0;
rti;
.ENDMOD;

```

III. Main Code

```

/* DSP Main Line code */
MODULE/RAM/ABS=0 main_line_code;
#define EXTERNAL PORT
#include <dsp.h>

```

```

#undef EXTERNAL
#define EXTERNAL GLOBAL
#include <dsp.h>
#undef EXTERNAL

.PORT      HMASK;
.VAR/DM    HIP_DATA0_SHADOW;
.VAR/DM    HIP_DATA1_SHADOW;
.VAR/DM    HIP_DATA2_SHADOW;
.VAR/DM    HIP_DSP_COMMAND_SHADOW;
.VAR/DM    HIP_TIMER_SHADOW;
.VAR/DM    HSR6_SHADOW;
.GLOBAL    HIP_DATA0_SHADOW;
.GLOBAL    HIP_DATA1_SHADOW;
.GLOBAL    HIP_DATA2_SHADOW;
.GLOBAL    HIP_DSP_COMMAND_SHADOW;
.GLOBAL    HIP_TIMER_SHADOW;
.GLOBAL    HSR6_SHADOW;
#include "dspcmd.h";
.EXTERNAL  SPORT0_tx_interrupt;
.EXTERNAL  sport1_rx_handle;
.EXTERNAL  initialize_transmit;
.EXTERNAL  process_transmit_command;
.EXTERNAL  process_receive_command;
.EXTERNAL  process_RSSI_command;
.EXTERNAL  process_parameter_command;
.EXTERNAL  process_powerdown_command;
.EXTERNAL  process_delay_command;
.EXTERNAL  slot_clock_period;
.EXTERNAL  stop_slot_timer;
.ENTRY     process_dsp_command;
.ENTRY     wait_for_dsp_command;
.ENTRY     queue_signal;
.VAR/DM/CIRC signal_queue[ 8 ];
.VAR/DM    waiting_for_HIP_read_flag;
// Interrupt Vector Table

      jump main;

```

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```
nop;
nop;
nop;
rti;
nop;
nop;
nop;
jump HIP_write_interrupt;
nop;
nop;
nop;
jump HIP_read_interrupt;
nop;
nop;
nop;
jump SPORT0_tx_interrupt;
nop;
nop;
nop;
rti;
nop;
nop;
nop;
rti;
nop;
nop;
nop;
rti;
nop;
nop;
rti;
nop;
nop;
rti;
nop;
nop;
jump SPORT1_rx_handle;
nop;
nop;
```

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```

    nop;
    rti;
    nop;
    nop;
    nop;
    idle;
    rti;
    nop;
    nop;

// DSP initialization
main:
    // Initialize interrupt controller
    IMASK = 0x0000;           { no interrupts enabled }
    ICNTL = 0;               { no nesting, IRQs level
sensitive }
    // initialize signal queue registers
    i6 = ^signal_queue;     /* write pointer */
    l6 = %signal_queue;
    m6 = 1;
    i3 = ^signal_queue;     /* read pointer */
    l3 = %signal_queue;
    m3 = 1;
    ax0 = 0;
    dm( waiting_for_HIP_read_flag ) = ax0;
    // initialize flag pins
    reset fl0;
    reset fl1;
    reset fl2;
    ax0 = 0x0400;
    DM( SYSTEM_CONTROL ) = ax0;
    AX0 = 0x0000;
    DM( DM_WAITSTATE_CONTROL ) = ax0;
// initialize sport 0
    DM( SPORT0_CONTROL ) = ax0;
    DM( SPORT0_TX_MULTICHANNEL_CONTROL0 ) = ax0;
    DM( SPORT0_TX_MULTICHANNEL_CONTROL1 ) = ax0;
    DM( SPORT0_RX_MULTICHANNEL_CONTROL0 ) = ax0;

```

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```

DM( SPORT0_RX_MULTICHANNEL_CONTROL1 ) = ax0;
DM( SPORT0_AUTOBUFFER_CONTROL ) = ax0;
// initialize sport 1
DM( SPORT1_CONTROL ) = ax0;
DM( SPORT1_AUTOBUFFER_CONTROL ) = ax0;
// Initialize the timer
DM( TIMER_TPERIOD ) = ax0;
DM( TIMER_TCOUNT ) = ax0;
DM( TIMER_TSCALE ) = ax0;
// enable HIP interrupts
*
*      ....  ....  ....  ...0 Host HDR0 Write (Data0)
*      ....  ....  ....  ..0. Host HDR1 Write (Data1)
*      ....  ....  ....  .0.. Host HDR2 Write (Data2)
*      ....  ....  ....  1... Host HDR3 Write (DSP Command)
*      ....  ....  ...0  .... Host HDR4 Write (DSP Signal)
*      ....  ....  ..0.  .... Host HDR5 Write (Timer)
*
*      ....  ...0  ....  .... Host HDR0 Read  (Data0)
*      ....  ..0.  ....  .... Host HDR1 Read  (Data1)
*      ....  .0..  ....  .... Host HDR2 Read  (Data2)
*      ....  0...  ....  .... Host HDR3 Read  (DSP Command)
*      ...1  ....  ....  .... Host HDR4 Read  (DSP Signal)
*      ..0.  ....  ....  .... Host HDR5 Read  (Timer)
*
*      xx01 0000 xx00 1000 = 0x1008
*/
ax0 = 0x1008;
DM( HMASK ) = ax0;
/*
* enable interrupts
*
*      ....  ....  ....  ...1 Timer interrupt
*      ....  ....  ....  ..1. Sport 1 receive
*      ....  ....  ....  .0.. Sport 1 transmit
*      ....  ....  ...0  0... Software interrupts
*      ....  ....  ..0.  .... Sport 0 receive
*      ....  ....  .1..  .... Sport 0 transmit

```

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```

*      ....  ....  1...  ....  Hip read
*      ....  ...1  ....  ....  Hip write
*      ....  ..0.  ....  ....  IRQ 2
*
*      xxxx xx01 1100 0011 = 0x01C3
*
*/
IMASK = IMASK_VALUE;
//initialize the different sections of code
call initialize_transmit;
// wait for command from the host
wait_for_dsp_command:
    idle;
    ax0 = dm( HSR6_SHADOW );
    ar = tstbit HSR_DSP_COMMAND_BIT of ax0;
    if eq jump wait_for_dsp_command;

process_dsp_command:
// HDR0 contains the command byte
si = DM( HIP_DSP_COMMAND_SHADOW );
// get the command type
sr = lshift si by HIP_DSP_COMMAND_SHIFT (LO);
// switch on command type
ar = sr0 - TRANSMIT_COMMAND;
if eq jump process_transmit_command;
ar = sr0 - RECEIVE_COMMAND;
if eq jump process_receive_command;
ar = sr0 - RSSI_COMMAND;
if eq jump process_RSSI_command;
ay0 = DELAY_COMMAND;
ar = sr0 - ay0;
if eq jump process_delay_command;
ay0 = POWERDOWN_COMMAND;
ar = sr0 - ay0;
if eq jump process_powerdown_command;
ar = pass sr0;
if eq jump process_parameter_command;
// invalid command

```

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```

        jump wait_for_dsp_command;

queue_signal:
    dis ints;
    // are we waiting for the previous signal to be read by
    ena sec_reg;
    ax1 = dm( waiting_for_HIP_read_flag );
    ar = pass ax1;
    if ne jump store_signal;
    // no: write signal to HIP
    ax1 = 1;
    dm( waiting_for_HIP_read_flag ) = ax1;
    dis sec_reg;
    dm( HIP_DSP_SIGNAL ) = ax0;
    set fl0;
    ena ints;
    rts;
    // yes: save signal for later

store_signal:
    dis sec_reg;
    dm( i6, m6 ) = ax0;
    ena ints;
    rts;

HIP_write_interrupt:
    // enable secondary registers
    ena sec_reg;
    // save HIP registers
    ax1 = dm( HSR6 );
    dm( HSR6_SHADOW ) = ax1;
    ax0 = dm( HIP_DATA0 );
    dm( HIP_DATA0_SHADOW ) = ax0;
    ax0 = dm( HIP_DATA1 );
    dm( HIP_DATA1_SHADOW ) = ax0;
    ax0 = dm( HIP_DATA2 );
    dm( HIP_DATA2_SHADOW ) = ax0;
    ax0 = dm( HIP_DSP_COMMAND );

```

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```

    ay0 = 0x00ff;
    ar = ax0 and ay0;
    dm( HIP_DSP_COMMAND_SHADOW ) = ar;
    rti;

HIP_read_interrupt:
// enable secondary registers
    ena sec_reg;
// check signal queue length
    ax0 = i6;
    ay0 = i3;
    ar = ax0 - ay0;
    if ne jump output_next_signal;
// signal queue is empty
    reset fl0;
    ax0 = 0;
    dm( HIP_DSP_SIGNAL ) = ax0;
    dm( waiting_for_HIP_read_flag ) = ax0;
    rti;
// signal queue is not empty
output_next_signal:
    ax0 = dm( i3, m3 );
    dm( HIP_DSP_SIGNAL ) = ax0;
    rti;
.ENDMOD;

```

IV. Delay Code

```

// DSP Delay code
MODULE/RAM Delay_code;
#include "dsp.h"
#include "dspcmd.h";
#include "hip.h"
.CONST SPORT1_ENABLE_BIT = 11;
// Delays are specified in multiples of 125 microseconds
.CONST COUNT_DELAY_PLL_STROBE = 8;    /* 1 miliseconds */
.CONST COUNT_DELAY_PLL_LOCK  = 24;    /* 3 miliseconds */
.EXTERNAL hextet_full;
.EXTERNAL process_dsp_command;

```

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```

.EXTERNAL wait_for_dsp_command;
.EXTERNAL queue_signal;
.EXTERNAL stop_sport1_serial_port;
.ENTRY process_delay_command;

process_delay_command:
// reset command that we received.
    ax0 = 0x0;
    DM(hip_dsp_command_shadow) = ax0;
// disable autobuffering
    dm( SPORT1_AUTOBUFFER_CONTROL ) = ax0;
/*
 * start sport 1
 *
 *      .... 1110 serial word length - 1
 *      .... ..00 .... data format 00 = right justify,
zero fill MSBs
 *      .... .1.. .... invert receive frame sync
 *      .... 1... .... invert transmit frame sync
 *      .... ...1 .... internal receive frame sync enable
 *      .... ..0. .... internal transmit frame sync
enable
 *      .... .1.. .... transmit frame sync width
 *      .... 1... .... transmit frame sync required
 *      .... ...1 .... receive frame sync width
 *      .... ..1. .... receive frame sync required
 *      .... .1.. .... internal serial clock generation
 *      0... .... multichannel enable
 *
 *      0111 1101 1100 1110 = 0x7dce
 */
    ax0 = 0x7DCE;
    dm( SPORT1_CONTROL ) = ax0;
/* * set up sport clock for 0.125 ms period
 *
 * delay    = 6 ms / 0.125 ms
 *          = 48
 *

```

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```

* main clock = 9.6 MHz
*
* period = 9 600 000 * 0.000125
*         = 1200
*/
ay1 = COUNT_DELAY_PLL_LOCK - COUNT_DELAY_PLL_STROBE;
ax1 = COUNT_DELAY_PLL_LOCK;
ax0 = 1 - 1;
dm( SPORT1_CLOCK_MODULUS ) = ax0;
ax0 = 1200 - 1;
dm( SPORT1_RX_FS_MODULUS ) = ax0;
// enable sport 1
ax0 = dm( SYSTEM_CONTROL );
ar = setbit SPORT1_ENABLE_BIT of ax0;
dm( SYSTEM_CONTROL ) = AR;
ax0 = 0x6000;
TX1 = ax0;
// wait for command from the host
wait_for_delay_timeout:
    ax0 = 0;
    dm( hextet_full ) = ax0;
    idle;
    ax0 = DM(hip_dsp_command_shadow);
    ar = PASS ax0;
    if eq jump not_terminate_delay;
        call stop_sport1_serial_port;
        jump process_dsp_command;
    not_terminate_delay:
    ax0 = dm( hextet_full );
    ar = pass ax0;
    if ne jump check_for_delay_timeout;
jump wait_for_delay_timeout;
check_for_delay_timeout:
// check for strobe delay completed
ar = ax1 - ay1;
if ne jump not_pll_strobe_delay_ended;
    ax0 = DELAY_PLL_STROBE;
    call queue_signal;

```

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```

    not_pll_strobe_delay_ended:
// check for lock delay completed
    ar = ax1 - 1;
    ax1 = ar;
    if ne jump wait_for_delay_timeout;
    call stop_sport1_serial_port;
    ax0 = DELAY_PLL_LOCK;
    call queue_signal;
    jump wait_for_dsp_command;
.ENDMOD;

```

V. IO Module

```

MODULE/RAM
io;
#include "dsp.h"
#include "dspcmd.h"
#include "hip.h"
.ENTRY      sport1_rx_handle;
.ENTRY      process_receive_command;
.EXTERNAL   wait_for_dsp_command;
.EXTERNAL   stop_slot_timer;
.EXTERNAL   new_slot_value;
.EXTERNAL   update_slot_timer;
.EXTERNAL   process_dsp_command;
.GLOBAL     hextet_full;
.GLOBAL     rssi_sample;
/* calls from decode.dsp */
.ENTRY      get_filtered_sample;
.ENTRY      adjust_sampling_and_read_rssi;
.ENTRY      init_filter;
/* calls to decode.dsp */
.EXTERNAL   start_decode;
.EXTERNAL   find_next_head;
/* network id (frame sync) for decode */
.EXTERNAL   network_id;
.CONST SERIAL1_ENABLE_BIT = 11;
.CONST      READ_AD_DESCRIMINATOR_WORD = 0x6000;
.CONST      READ_AD_RSSI_WORD = 0x7000;
.CONST      OVERSAMPLING = 6;

```

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```

.VAR/DM/CIRC      hextet_buffer[OVERSAMPLING];
.VAR/DM           hextet_full;
.VAR/DM           rssi_sample;                /* for continuous
rssi readings */

.CONST            PAST_SIZE = 36;
.VAR/DM/CIRC      past_samples[PAST_SIZE];
.INIT             past_samples:
0x4000,0x4000,0x4000,0x4000,0x4000,0x4000,
0x4000,0x4000,0x4000,0x4000,0x4000,0x4000,
0x4000,0x4000,0x4000,0x4000,0x4000,0x4000,
0x4000,0x4000,0x4000,0x4000,0x4000,0x4000,
0x4000,0x4000,0x4000,0x4000,0x4000,0x4000,
0x4000,0x4000,0x4000,0x4000,0x4000,0x4000;
.CONST            FILTER_LENGTH = 24;
.VAR/PM/CIRC      filter_response[FILTER_LENGTH];
.INIT             filter_response:
0x003e00,0x003600,0xffff00,0xff9900,0xff2c00,0xfefc00,
0xff5100,0x005500,0x01f900,0x03e700,0x05a100,0x06a500,
0x06a500,0x05a100,0x03e700,0x01f900,0x005500,0xff5100,
0xfefc00,0xff2c00,0xff9900,0xffff00,0x003600,0x003e00;
/* Command interpreter */
process_receive_command:
    ax0 = dm(hip_dsp_command_shadow);
    ar = ax0 - RECEIVE_STOP_SLOT_CLOCK;
    /* if we get issued an invalid receive command from
mainline, then we should */
    /* not not restore it as this will cause an infinite
loop. Put a bogus */
    /* value into ax0 and jump into the appropriate place.
*/
    /* on the other hand, if we receive a bogus receive
command during receive */
    /* we pass it back to mainline, receive it here, and
then discard it. */
    ax0 = 0;
    call restore_command_impossible_kluge;
    jump wait_for_dsp_command;

```

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```

process_command_during_receive:
    ax0 = dm(hip_dsp_command_shadow);          /* read hip
host command location */
    ar = pass 0;                                /* wipe out
the command. */
    dm(hip_dsp_command_shadow) = ar;          /* so it will
not be re-processed */
    ar = ax0 - RECEIVE_STOP_SLOT_CLOCK;
    /* first check for commands that execute without
interrupting the program flow */
    /* these commands will execute an 'rts' and cause
regular receive processing */
    /* to resume upon completion. */

restore_command_impossible_kluge:
    if eq jump stop_slot_timer;
.CONST xx1 = RECEIVE_SLOT_LENGTH - RECEIVE_STOP_SLOT_CLOCK;
    ar = ar - xx1;
    if eq jump new_slot_value;

    pop cntr, pop pc, pop loop;
    pop cntr, pop pc, pop loop;
    pop cntr, pop pc, pop loop;
    pop cntr, pop pc, pop loop;
    pop cntr, pop pc, pop loop;

.CONST xx2 = RECEIVE_LOAD_FRAME_SYNC - RECEIVE_SLOT_LENGTH;
    ar = ar - xx2;
    /* test RECEIVE_LOAD_FRAME_SYNC */
    if eq jump loadframesync;
.CONST xx3 = RECEIVE_NEXT_HEAD - RECEIVE_LOAD_FRAME_SYNC;
    ar = ar - xx3;
    if eq jump find_next_head;
.CONST xx4 = RECEIVE_START - RECEIVE_NEXT_HEAD;
    ar = ar - xx4;
    if eq jump initialize_receive;
    dm(hip_dsp_command_shadow) = 0;

```

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```

        ax0 = dm( SYSTEM_CONTROL );           /* rx done.
Disable sport1 */
        ar = clrbit serial1_enable_bit of ax0;
        dm( SYSTEM_CONTROL ) = ar;
        ax0 = 0;
        dm( SPORT1_CONTROL ) = ax0;
        jump process_dsp_command;

loadframesync:
        si = dm(HIP_DATA0);
        sr = lshift si by 8 (lo);
        ay0 = dm(HIP_DATA1);
        ar = sr0 or ay0;
        dm(network_id) = ar;
        rts;

initialize_receive:
/*-----Initialize SP1 control registers -----
-----*/

        /*..11...1.1..... = rx internal frame sync, alternate
framing, active low */
        /*....110.1..... = tx external frame sync, alternate
framing, active low */
        /*.1..... = internal serial clock
*/
        /*.....00.... = right justify, zero fill unused
MBS' */
        /*.....1110 = 15 bit word length
*/
        /*0111110111001110 = 0x7DCE
*/

        ax0 = 0x7DCE;
        dm(SPORT1_CONTROL) = ax0;
        ax0 = 1-1;           /* Make 9.6 Mhz SCLK1 */
        dm(SPORT1_CLOCK_MODULUS)=ax0;           /* from 9.60
MHZ CLKIN */

```

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```

        ax0 = 200-1;                                /* divide by
200 for 48 khz                                     */
        dm(SPORT1_RX_FS_MODULUS)=ax0;                /* 6x
oversampling                                     */

        /*....00000.....0. = tx autobuffering disabled
        */
        /*.....00000.1 = rx autobuffering using i0 m0 10
        */
        /*000000000000000001 = 0x0001
        */
        ax0=0x0001;
        dm(SPORT1_AUTOBUFFER_CONTROL)=ax0;
        i0 = ^hextet_buffer;                          /* set up
hextet buffer                                     */
        l0 = 6;
        m0 = 1;
        ax0 = 0;
        dm(hextet_full) = ax0;
        ax0 = READ_AD_DESCRIMINATOR_WORD;              /* set up to
read discriminator                               */
        tx1 = ax0;                                      /* is
transmitted by default                           */
        dis M_MODE;                                    /* configure
MAC for 1.15 arithmetic */

        ax0 = DM( SYSTEM_CONTROL );                    /* enable
sport 1                                           */
        ar = SETBIT SERIAL1_ENABLE_BIT of ax0;
        dm( SYSTEM_CONTROL ) = ar;

        call stop_slot_timer;                          /* inititalize /
kill old slots                                     */
        jump start_decode;

/* Wait for 6 new samples and then return          */
get_hextet:

```

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```

        imask = 0;                                /* begin
critical section                                */
        ax0 = dm(hip_dsp_command_shadow);
        ar = pass ax0;
        if eq jump not_command;
            imask = IMASK_VALUE;
            call process_command_during_receive;
            jump get_hextet;
        not_command:
        ax0 = dm(hextet_full);    /* is fifo empty ? */
        ar = pass ax0;
        if ne jump got_new_hextet;
        /* Note: Manipulating imask directly instead of
disabling interrupt.    */
        /* this is necessary, as manipulating imask will
disable interrupts for    */
        /* one cycle, which will knock us out of idle mode if
we enter it at a bad    */
        /* time.    */
        imask = IMASK_VALUE;                                /* end
critical section                                */
        idle;
        jump get_hextet;

got_new_hextet:
        imask = IMASK_VALUE;
        ax0 = 0;
        dm(hextet_full) = ax0;

        call update_slot_timer;
        rts;

// interrupt service routine
sport1_rx_handle:
        ena sec_reg;
        ax0 = 1;
        dm(hextet_full) = ax0;
        dm(rssi_sample) = rx1;

```

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```

        rti;
// Initialize filter state
init_filter:
        i1 = ^past_samples + FILTER_LENGTH - OVERSAMPLING;
        l1 = PAST_SIZE;
        m1 = 1;
        i2 = ^past_samples;
        l2 = PAST_SIZE;
        rts;
// Get one decimated sample
get_filtered_sample:
        call get_hextet;
        i4 = ^hextet_buffer;
        l4 = 0;
        m4 = 1;
        cntr = 6;
        se = 8;
        si = dm(i4,m4);
        /* this loop shifts the data left by 8 */
        do copy_loop until ce;
                sr = lshift si (lo), si = dm(i4,m4);
copy_loop:  dm(i1,m1) = sr0;
        /* apply the fir filter by multiplying and
accumulating. */
        i4 = ^filter_response;
        /* l4 = 0; already 0 */
        /* m4 = 1; already */
        cntr = FILTER_LENGTH-1;
        mx0 = dm(i2,m1), my0 = pm(i4,m4), mr = 0;
        do filter_mac until ce;
filter_mac: mr = mr + mx0 * my0 (us) ,mx0 = dm(i2,m1), my0 =
pm(i4,m4);
        mr = mr + mx0 * my0 (us);
        m2 = PAST_SIZE - FILTER_LENGTH + OVERSAMPLING;
        /* restore original indices */
        modify(i2,m2);
        /* return value in mrl, with a range of 0 to 16384 */
        rts;

```

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```

adjust_sampling_and_read_rssi:
    m2 = sr0;
    /* modify i2, the read point, by adjustment factor */
    modify(i2,m2);
    ax0 = i2;          /* read point */
    ay0 = i1;          /* write point */
    ar = ay0 - ax0; /* write point - read point */
    ay0 = PAST_SIZE;
    if lt ar = ar + ay0;
    /* ar now has a value from 0 to PAST_SIZE-1 */
    /* three possibilities:
    1) FILTER_LENGTH-OVERSAMPLING <= ar < FILTER_LENGTH
       no adjustment necessary
    2) FILTER_LENGTH <= ar
       add OVERSAMPLING to read point
    3) ar <= FILTER_LENGTH-OVERSAMPLING
       subtract 6 from read point */
    m2 = 0;
    ay0 = FILTER_LENGTH-OVERSAMPLING;
    af = ar - ay0;
    if ge jump not1;
        /* ar <= FILTER_LENGTH-OVERSAMPLING */
        m2 = -OVERSAMPLING;
    not1:
    ay0 = FILTER_LENGTH;
    af = ar - ay0;
    if lt jump not2;
        /* FILTER_LENGTH <= ar */
        m2 = OVERSAMPLING;
    not2:
    modify(i2,m2);
    ax0 = ^hextet_buffer + OVERSAMPLING-1;
    wait:
        ay0 = i0;
        ar = ax0 - ay0;
    if ne jump wait;
    /* switch channels */
    ay0 = READ_AD_RSSI_WORD;

```

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```

    tx1 = ay0;
    /* wait for next rx sample to be aquired */
    wait2:
        ay0 = i0;
        ar = ax0 - ay0;
    if eq jump wait2;
    ax0 = READ_AD_DESCRIMINATOR_WORD;
    tx1 = ax0;
    /* save RSSI sample into ay0 */
    ay0 = dm(hextet_buffer+OVERSAMPLING-1);
    /* fix rssi sample by copying in sample from after it
    */
    ax0 = dm(hextet_buffer);
    dm(hextet_buffer+OVERSAMPLING-1) = ax0;
    /* rssi sample is returned in AY0 */
    rts;
.ENDMOD;

```

VI. Parameter Initialization Module

```

// DSP Parameter Initialization code
.MODULE/RAM parameter_initialization_code;
#include "dsp.h"
#include "hip.h"
#include "dspcmd.h";
.EXTERNAL wait_for_dsp_command;
.EXTERNAL queue_signal;
.ENTRY process_parameter_command;

process_parameter_command:
    ax0 = 0x0;
    dm( HSR6_SHADOW ) = ax0;
    ax0 = dm( HIP_DSP_COMMAND_SHADOW );
    ar = ax0 - 1;
    if ne jump wait_for_dsp_command;
    ax0 = 2;
    call queue_signal;
    jump wait_for_dsp_command;

```

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.ENDMOD;

VII. Powerdown Module

```
// DSP Powerdown code
.MODULE/RAM powerdown_code;
#include "dsp.h"
#include "dspcmd.h";
.EXTERNAL wait_for_dsp_command;
.ENTRY process_powerdown_command;

process_powerdown_command:
// powerdown dsp
    ax0 = dm( SPORT1_AUTOBUFFER_CONTROL );
    ar = setbit 13 of ax0;
    dm( SPORT1_AUTOBUFFER_CONTROL ) = ar;
    jump wait_for_dsp_command;
.ENDMOD;
```

VIII. RSSI Module

```
// DSP RSSI code
.MODULE/RAM RSSI_code;
#include "dsp.h"
#include "dspcmd.h";
#include "hip.h"
.CONST SPORT1_ENABLE_BIT = 11;
.CONST INITIAL_DISCARD_SAMPLE_COUNT = 2;
.CONST MAXIMUM_SAMPLE_COUNT = 255;
.EXTERNAL hextet_full;
.EXTERNAL rssi_sample;
.EXTERNAL process_dsp_command;
.EXTERNAL wait_for_dsp_command;
.EXTERNAL queue_signal;
.ENTRY process_RSSI_command;
.ENTRY stop_sport1_serial_port;
.VAR/DM discard_sample_count;
.VAR/DM collected_sample_count;

process_RSSI_command:
```

```

    set fl2;
// reset flags
    ax0 = 0;
    dm( hextet_full ) = ax0;
    ax0 = INITIAL_DISCARD_SAMPLE_COUNT;
    dm( discard_sample_count ) = ax0;
    ax0 = MAXIMUM_SAMPLE_COUNT;
    dm( collected_sample_count ) = ax0;
/*
    * initialize register variables
    *
    * ax1 = number of samples
    * ay0 = LSW of accumulated samples
    * af = MSW of accumulated samples
    *
    * af is set to 0 since we do not expect to need more than
16 bits
    * to store the accumulated samples. */
    ax1 = 0;
    ay0 = 0;
    af = pass 0;
    jump validate_RSSI_command;
wait_for_RSSI_command:
    idle;
    ax0 = dm( HSR6_SHADOW );
    ar = tstbit HSR_DSP_COMMAND_BIT of ax0;
    if ne jump validate_RSSI_command;
    ax0 = dm( hextet_full );
    ar = pass ax0;
    if ne jump collect_RSSI_sample;
    jump wait_for_RSSI_command;
validate_RSSI_command:
    ax0 = 0x0;
    dm( HSR6_SHADOW ) = ax0;
// fetch the command byte
    ax0 = dm( HIP_DSP_COMMAND_SHADOW );
// switch on command type
    ay1 = RSSI_START_COMMAND;

```

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```

    ar = ax0 - ay1;
    if eq jump start_RSSI_command;
    ay1 = RSSI_STOP_COMMAND;
    ar = ax0 - ay1;
    if eq jump stop_RSSI_command;
// invalid RSSI command
    call stop_sport1_serial_port;
    reset fl2;
    nop;
    set fl2;
    nop;
    reset fl2;
    jump process_dsp_command;

start_RSSI_command:
// disable autobuffering
    ax0 = 0;
    dm( SPORT1_AUTOBUFFER_CONTROL ) = ax0;
/ * start sport 1
*
*      .... 1110 serial word length - 1
*      .... ..00 .... data format 00 = right justify,
zero fill MSBs
*      .... .1.. .... invert receive frame sync
*      .... 1... .... invert transmit frame sync
*      .... ...1 .... internal receive frame sync enable
*      .... ..0. .... internal transmit frame sync
enable
*      .... .1.. .... transmit frame sync width
*      .... 1... .... transmit frame sync required
*      ...1 .... .... receive frame sync width
*      ..1. .... .... receive frame sync required
*      .1.. .... .... internal serial clock generation
*      0... .... .... multichannel enable
*
*      0111 1101 1100 1110 = 0x7dce
*/
    ax0 = 0x7DCE;

```

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```

    dm( SPORT1_CONTROL ) = ax0;
    ax0 = 1 - 1;
    dm( SPORT1_CLOCK_MODULUS ) = ax0;
    ax0 = 19200 - 1;
    dm( SPORT1_RX_FS_MODULUS ) = ax0;
    // enable sport 1
    ax0 = dm( SYSTEM_CONTROL );
    ar = setbit SPORT1_ENABLE_BIT of ax0;
    dm( SYSTEM_CONTROL ) = AR;
    ax0 = 0x7000;
    TX1 = ax0;
    jump wait_for_RSSI_command;

stop_RSSI_command:
    reset fl2;
    call stop_sport1_serial_port;
    /* divide accumulated RSSI values by number of samples
    *
    * ax1 = divisor (number of samples)
    * af = MSW of dividend (0)
    * ay0 = LSW of divided (accumulated RSSI value)
    *
    * ay0 will contain quotient
    */
    ASTAT = 0;
    dm( HIP_DATA2 ) = ax1 ;
    si = ay0;
    sr = lshift si by 1 (LO);
    ay0 = sr0;
    af = pass srl;
    CNTR = 16;
    do divide_loop until ce;
divide_loop: divq ax1;
    // write quotient to HIP
    dm( HIP_DATA0 ) = ay0;
    ax0 = dm( rssi_sample );
    dm( HIP_DATA1 ) = ax0;
    ax0 = RSSI_COMPLETED;

```

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```
    call queue_signal;
    jump wait_for_dsp_command;

collect_RSSI_sample:
    toggle fl2;
// reset flag indicating new sample
    ax0 = 0;
    DM(hextet_full) = ax0;
    ax0 = dm( discard_sample_count );
    ar = ax0 - 1;
    if eq jump get_new_sample;
    dm( discard_sample_count ) = ar;
    jump wait_for_RSSI_command;

get_new_sample:
// only collect 255 samples maximum
    ax0 = dm( collected_sample_count );
    ar = ax0 - 1;
    if eq jump wait_for_RSSI_command;
    dm( collected_sample_count ) = ar;
// get new sample
    ax0 = dm( rssi_sample );
    ay1 = 255;
    ar = ax0 and ay1;
// accumulate new sample
    ar = ar + ay0;
    ay0 = ar;
// increment number of samples
    ar = ax1 + 1;
    ax1 = ar;
    jump wait_for_RSSI_command;

stop_sport1_serial_port:
    ax0 = dm( SYSTEM_CONTROL );
    ar = clrbit SPORT1_ENABLE_BIT of ax0;
    dm( SYSTEM_CONTROL ) = ax0;
    ax0 = 0;
    dm( SPORT1_CONTROL ) = ax0;
```

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```

    rts;
.ENDMOD;

```

IX. Timer Code Module for slot clock timing

```

.MODULE/RAM timer_code;
.EXTERNAL queue_signal;
#include "dsp.h"
#include "dspcmd.h"
.CONST INITIAL_SLOT_CLOCK_PERIOD = 35 * 256 + 256;
.EXTERNAL wait_for_dsp_command;
.ENTRY start_slot_timer;
.ENTRY stop_slot_timer;
.ENTRY update_slot_timer;
.ENTRY new_slot_value;
.VAR/DM slot_clock_period;
.GLOBAL slot_clock_period;
.VAR/DM countdown;
.VAR/DM slot_count_start;
/* Start the slot timer - called from decode. */
start_slot_timer:
    ax0 = 320; /* 40 milliseconds at 8 khz ticks */
    dm(countdown) = ax0;
    rts;
/* Called to stop the timer from runing. */
stop_slot_timer:
    ax0 = 0;
    dm(countdown) = ax0;
    rts;
/* This routine is called 8000 times per second while receive
is active. */
update_slot_timer:
    ax0 = dm(countdown);
    ar = pass ax0;
    if eq rts;
    ar = ax0 - 1;
    dm(countdown) = ar;
    if ne rts;

```

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```
        /* counter has just counted down to zero.  Time for
slot clock time! */
        ax0 = RECEIVED_SLOT_CLOCK;
        call queue_signal;
        ax0 = dm(slot_count_start);
        dm(countdown) = ax0;
        rts;
/* This routine is called when the slot length has changed
   */
new_slot_value:
        si = dm(HIP_TIMER);
        sr = lshift si by 8 (lo);    /* convert to multiples of
8 khz                                */
        sr = lshift sr0 by -3 (lo); /* while truncating
unwanted bits with                */
        dm(slot_count_start) = sr0;
        rts;
.ENDMOD;
```

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CLAIMS

1. A wireless radio modem for transferring data between a host data processing device and a remote data processing device or a data transmission/reception network station comprising transmission/reception means for transferring data at radio frequencies between the host data processing device and at least one of the remote data processing device and the data transmission/reception network station and modulation/demodulation means wherein the modulation/demodulation means comprises means for demodulating data received from the transmission/reception means and means for modulating data generated by the host data processing device, wherein the means for demodulating data includes frequency discrimination means having one or more electronically-coupled piezoelectric phase-shift devices and the means for modulating data includes a digital signal processor with a waveform transition look-up table stored in a storage area and generated using single sideband suppressed carrier modulation and an orthogonal component mixer circuit operationally connected to the digital signal processor to create a modulated output data signal.
2. The wireless radio modem of claim 1 wherein the transmission/reception means and the modulation/demodulation means are together physically enclosed within the host data processing device.

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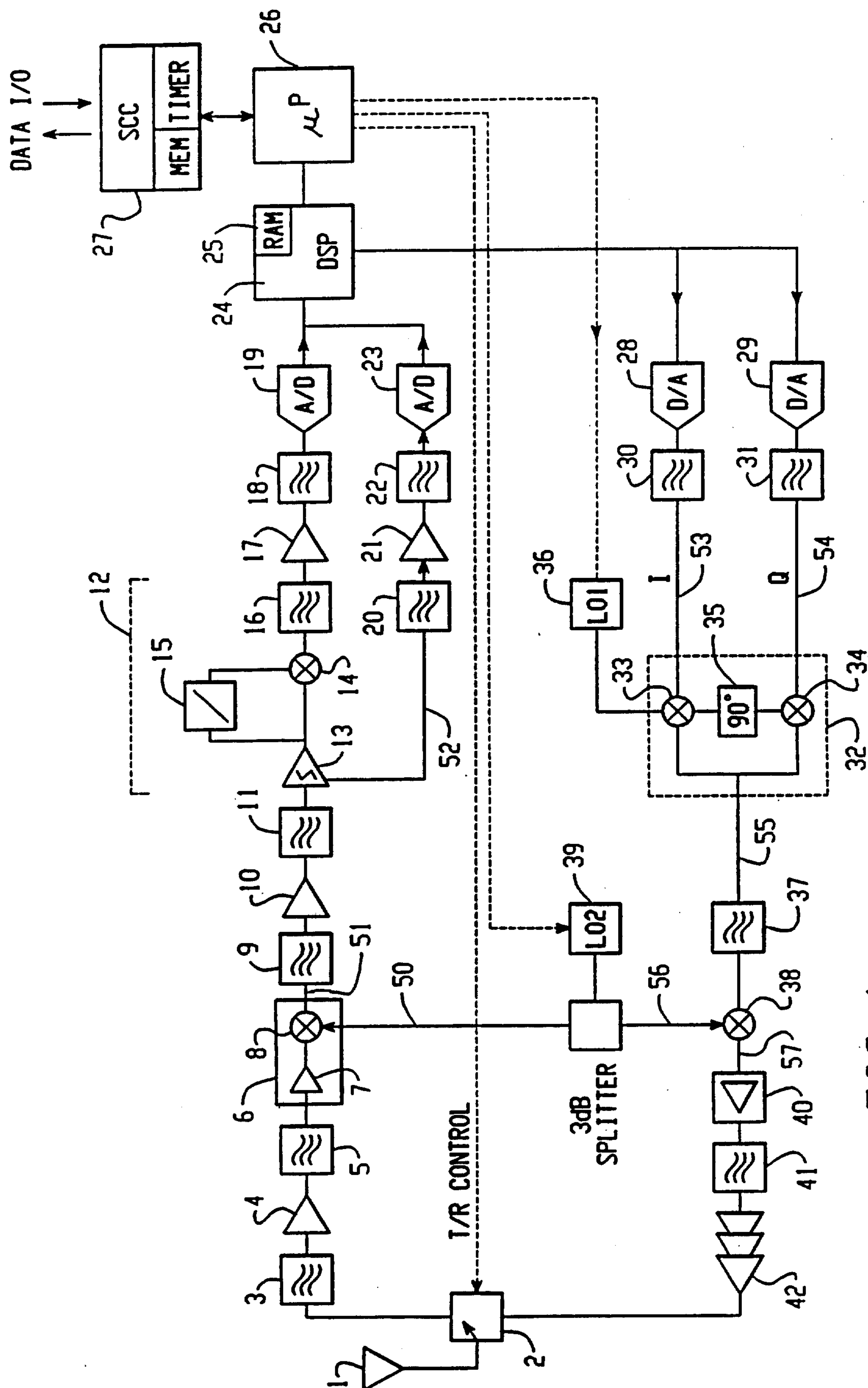


FIG. 1a

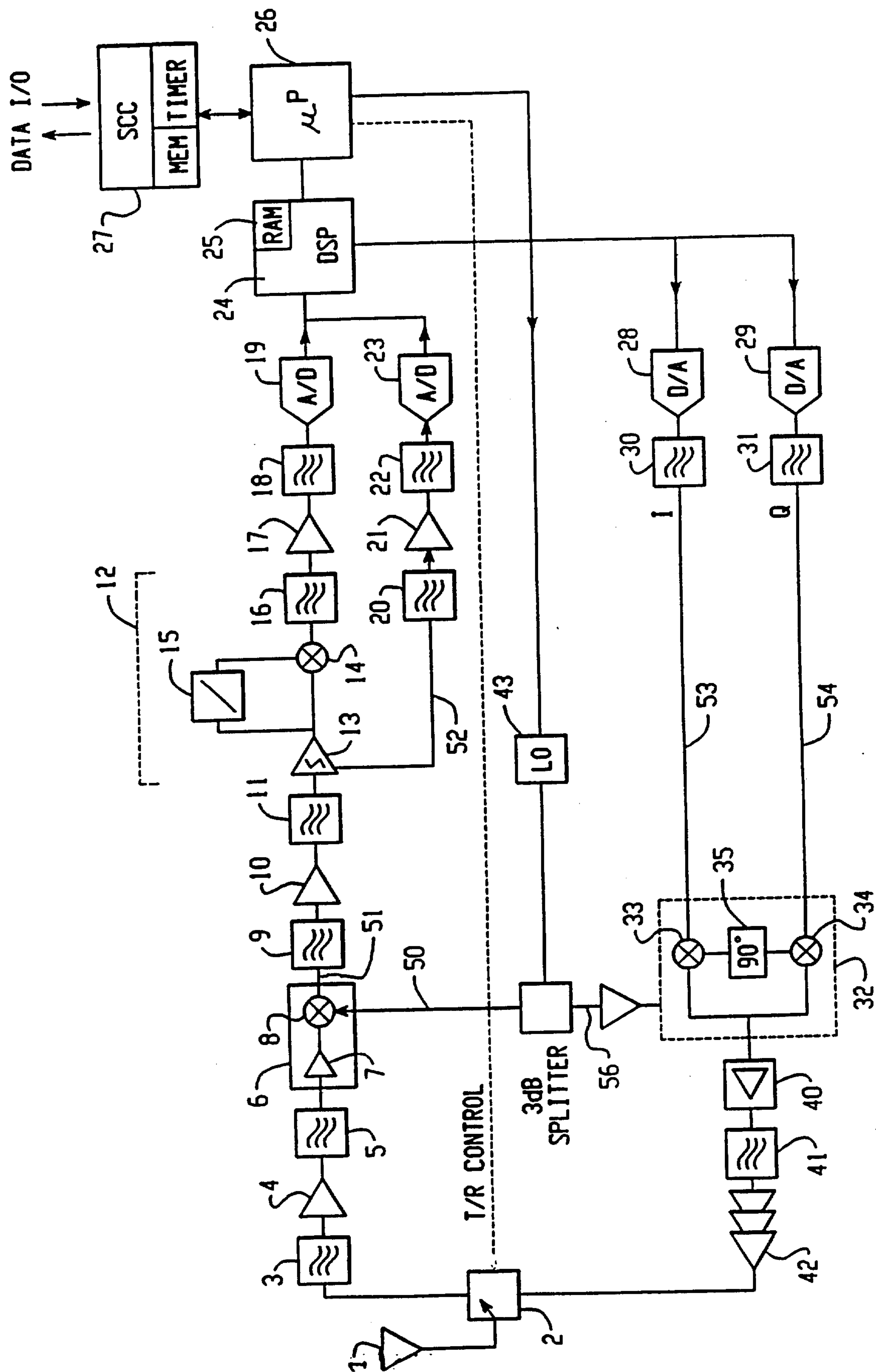


FIG. 1b

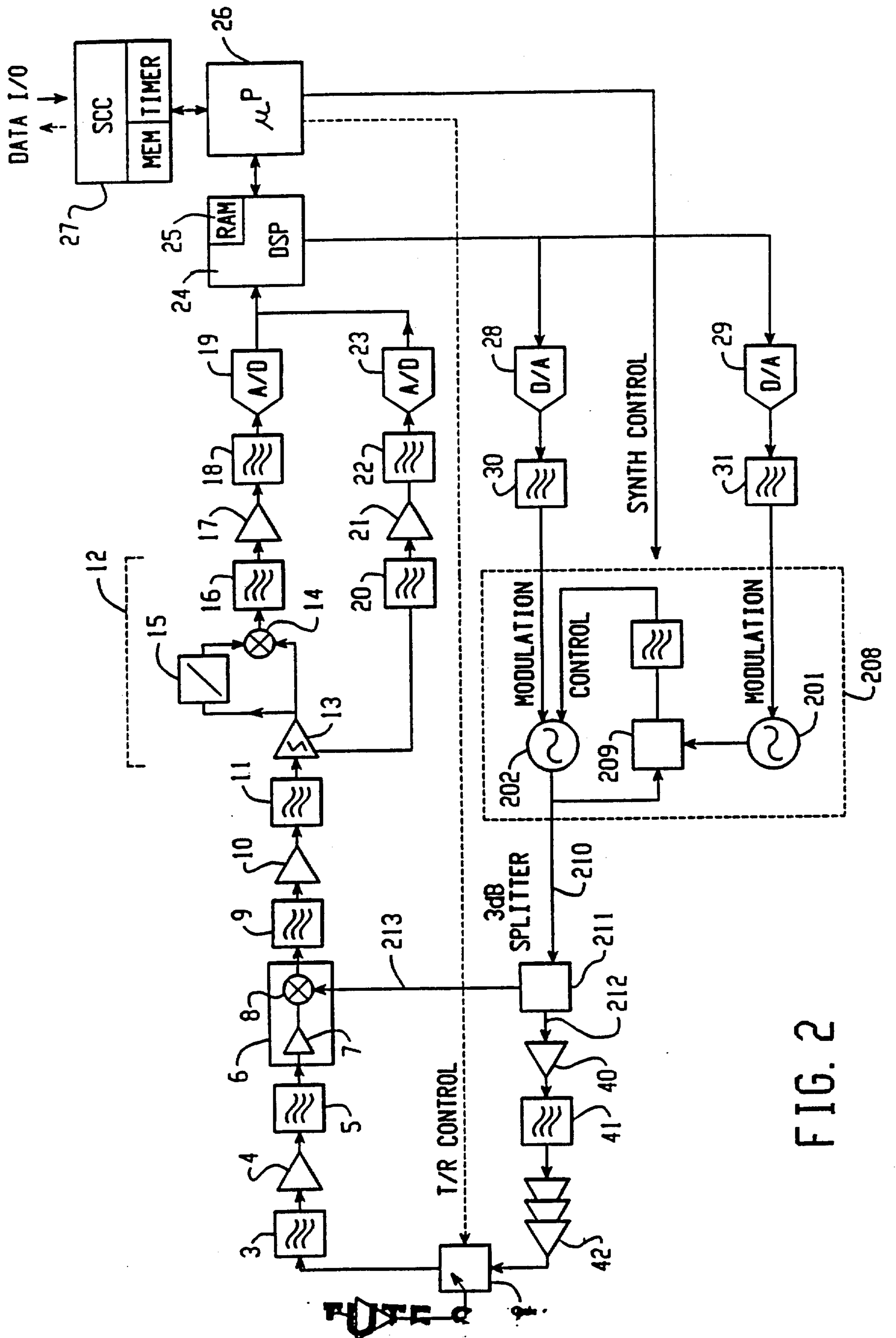


FIG. 2

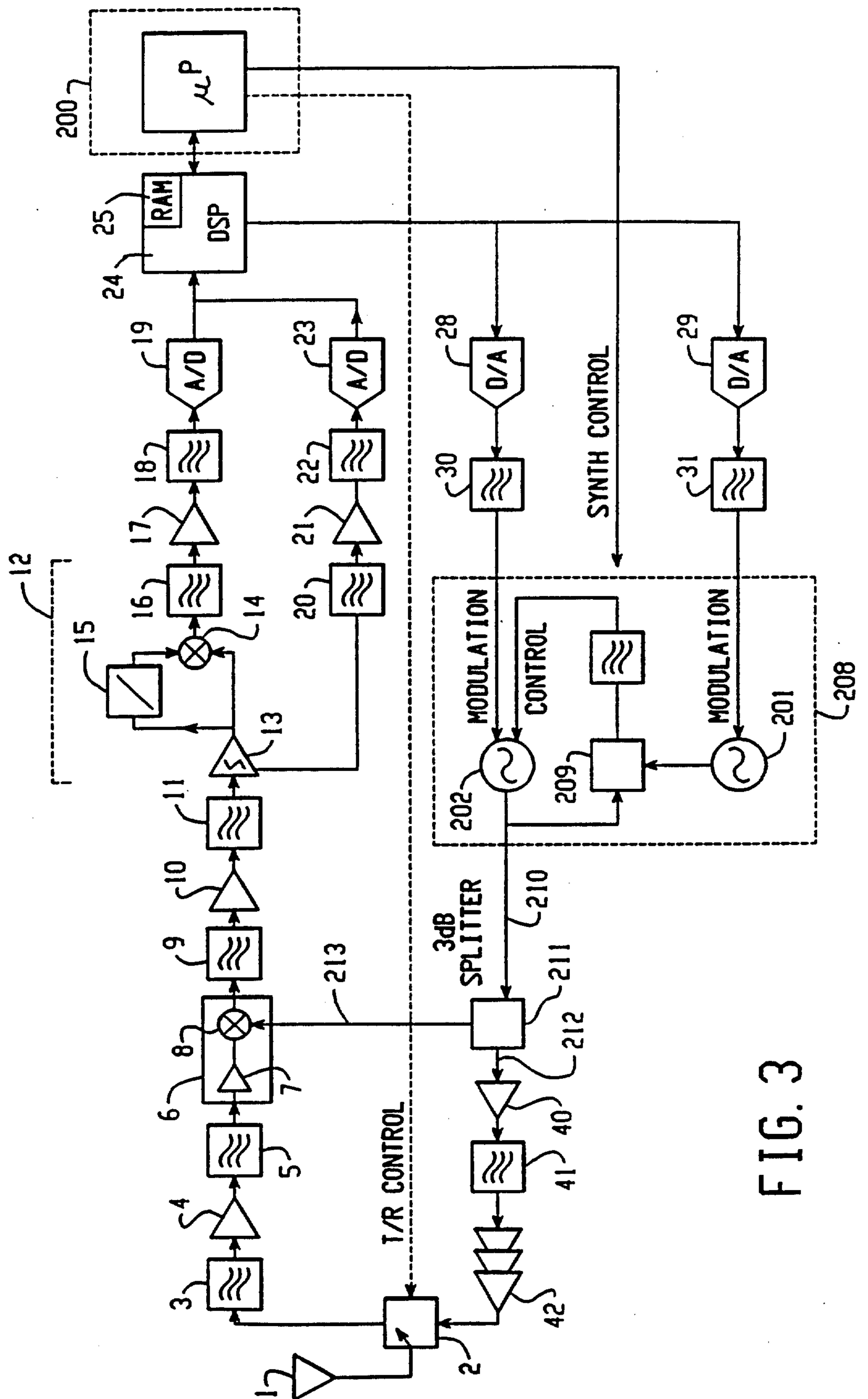


FIG. 3

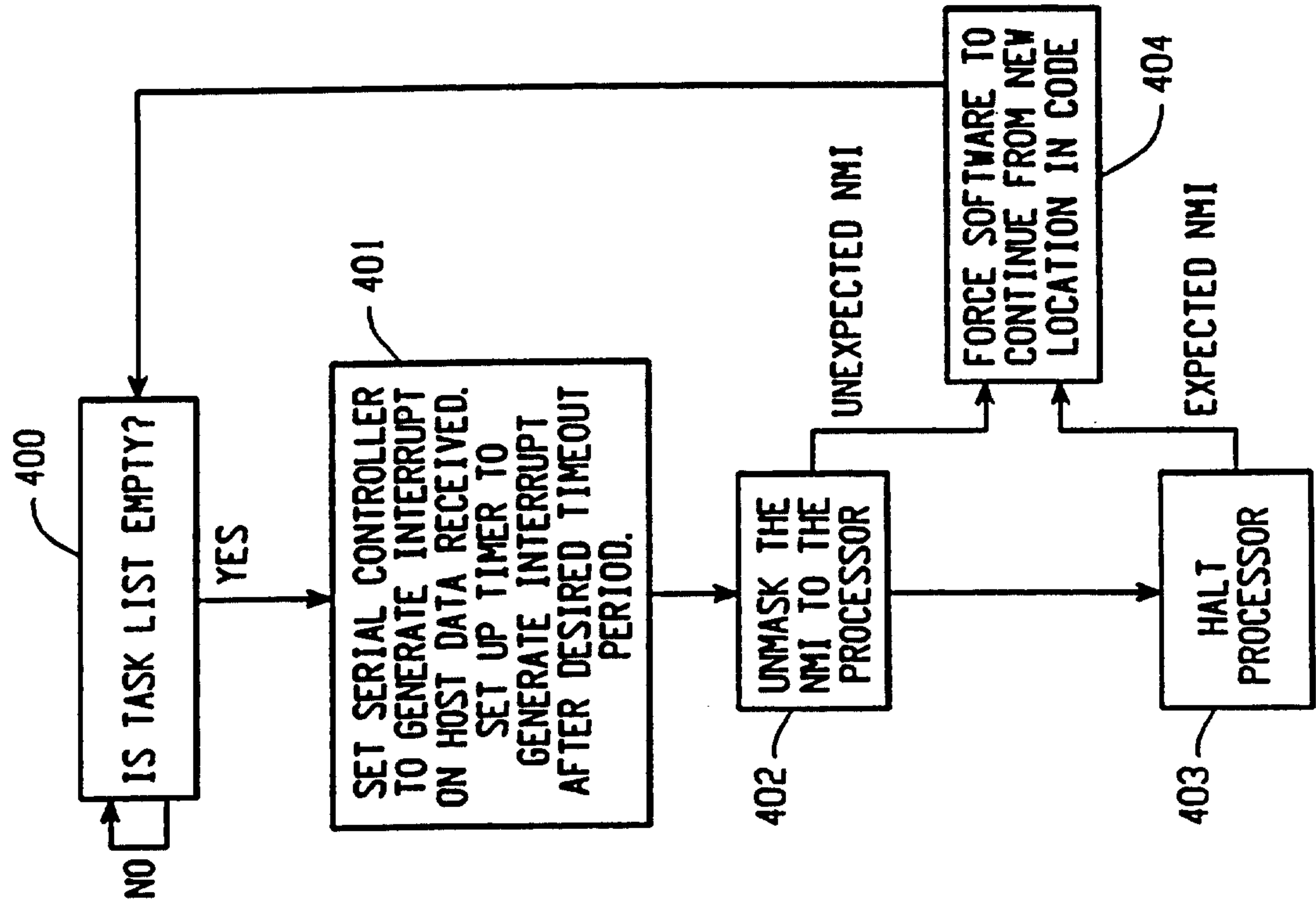


FIG. 4

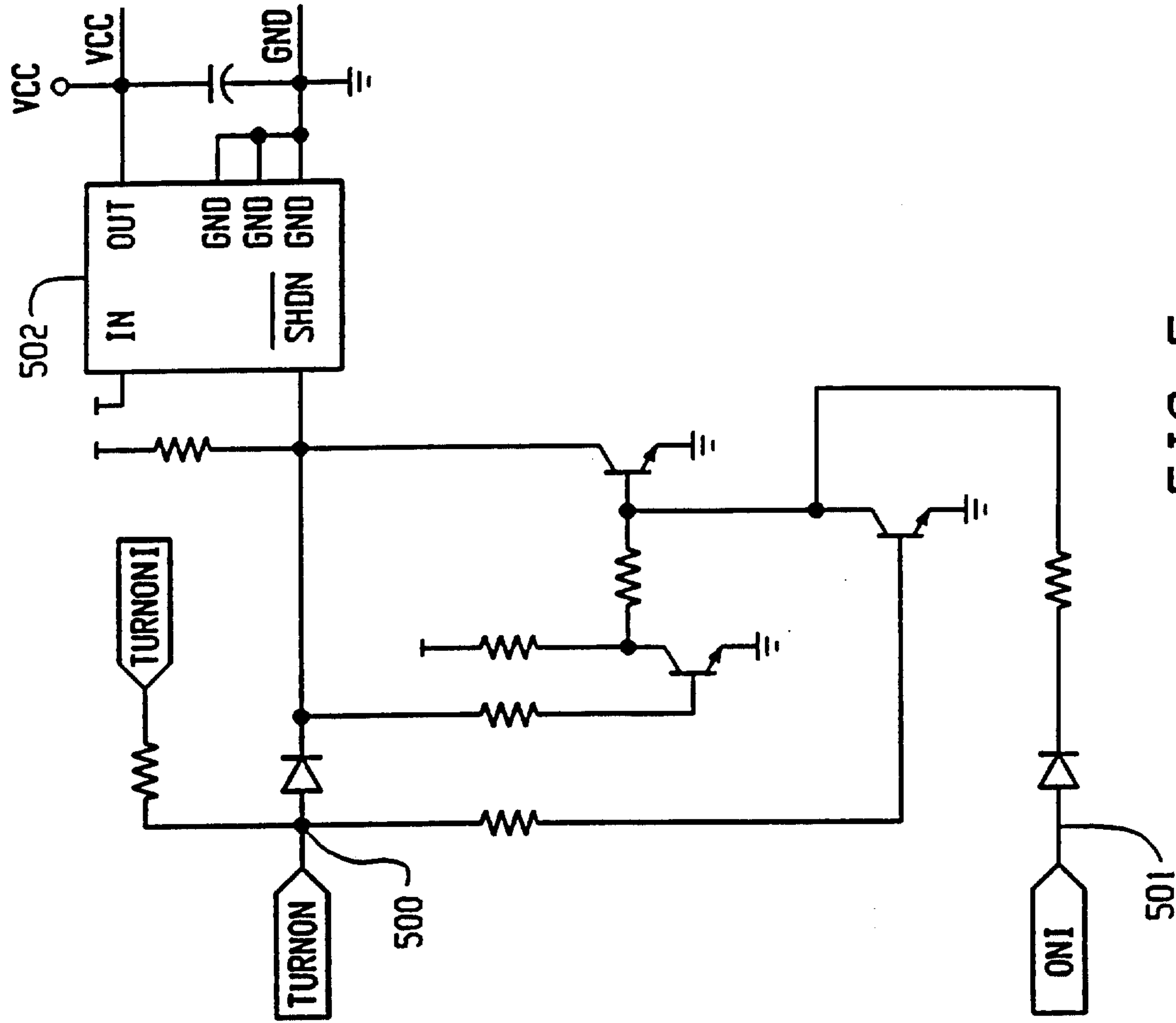


FIG. 5

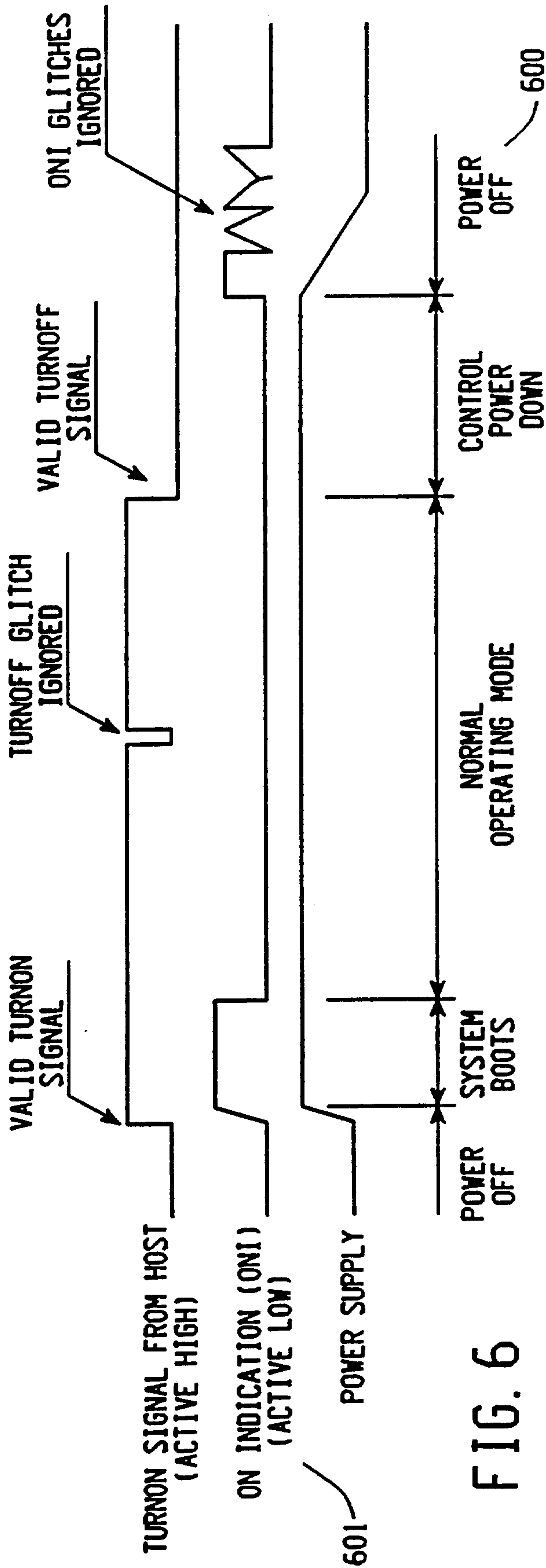


FIG. 6

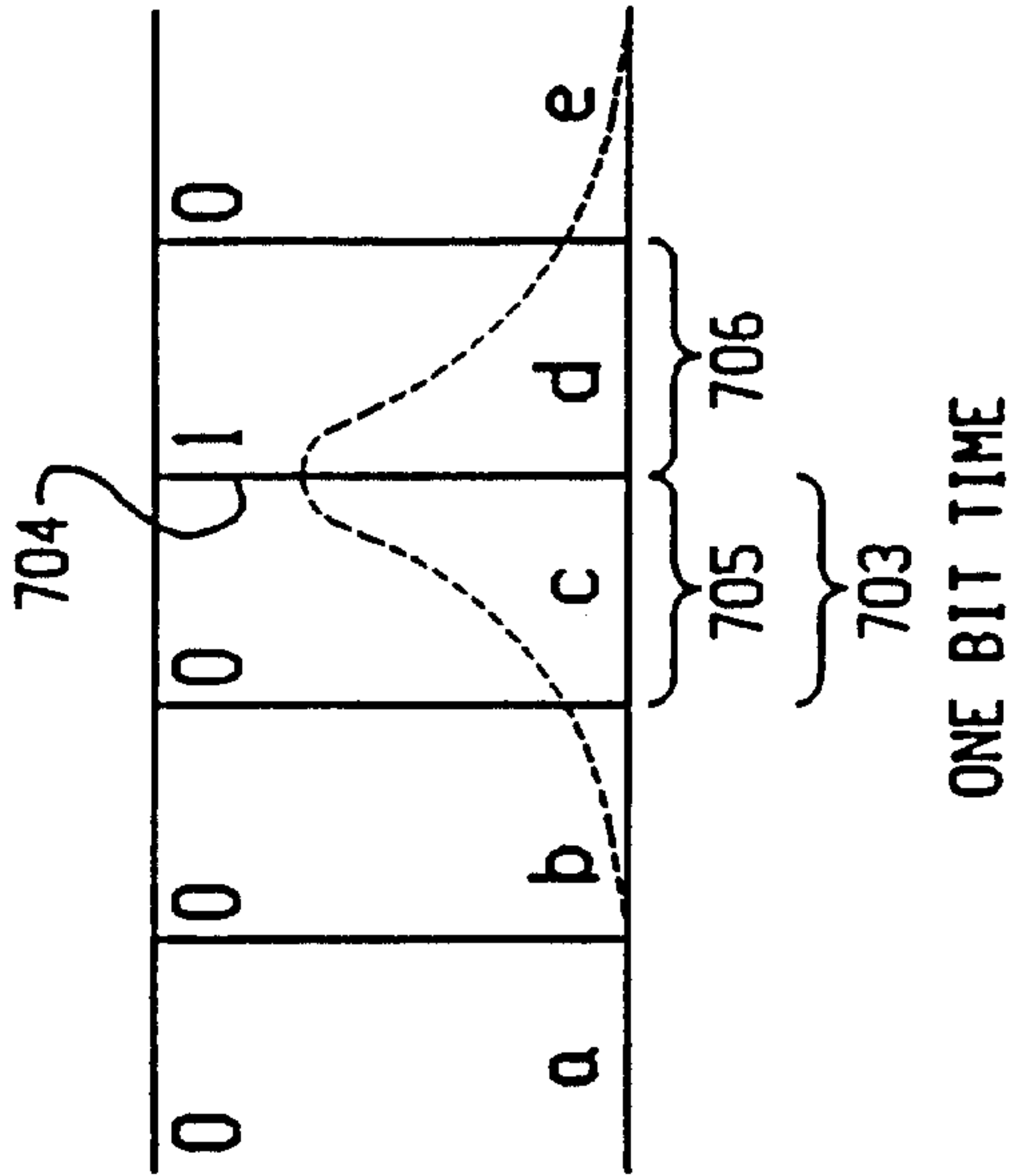


FIG. 7a

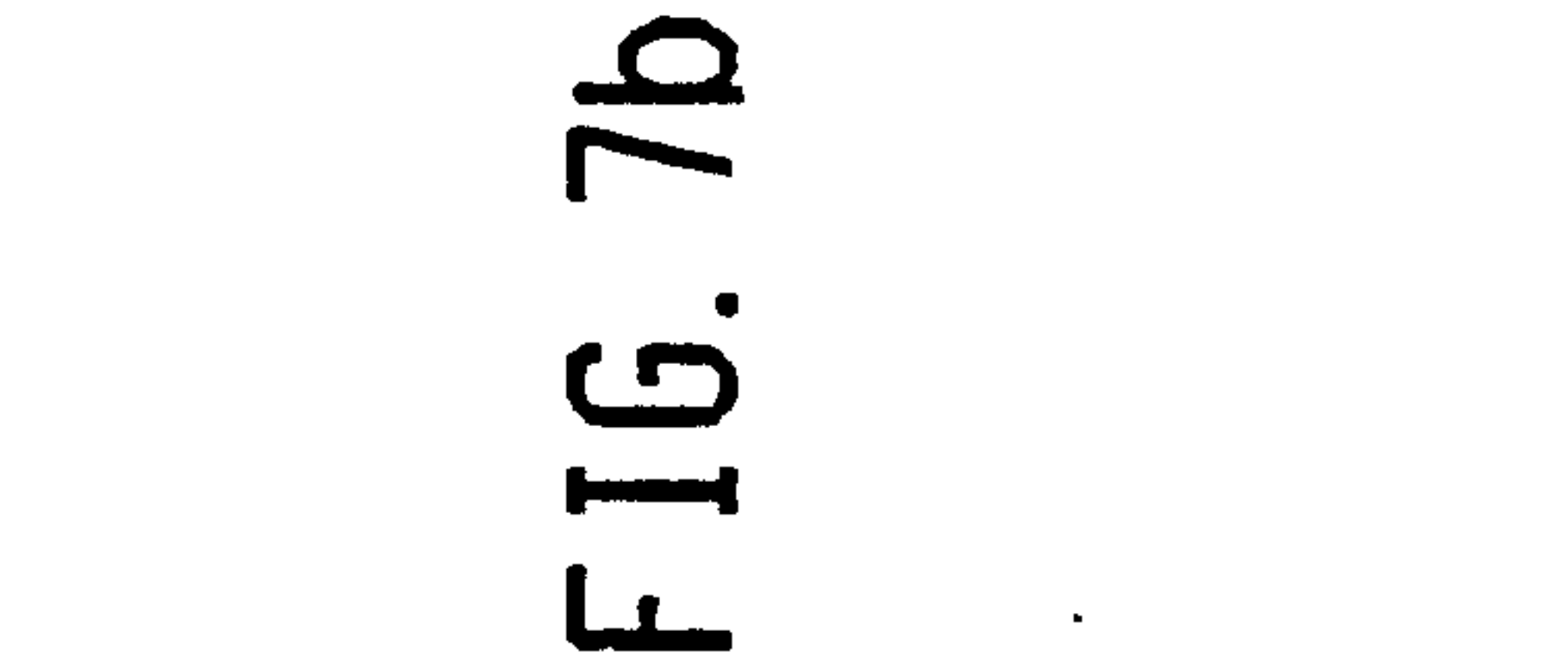


FIG. 7b

