AN ECONOMICAL HIGH SPEED SATELLITE DATA TRANSMISSION SYSTEM

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ABSTRACT

This paper will present and review the techniques and considerations used for delivery of 28 channels of CD quality digital audio via one satellite transponder. Subjects include bandwidth, tolerable bit error rates, forward error correction, and carrier to noise ratios.

INTRODUCTION

The design and implementation of a high speed satellite data transmission system requires optimizing all the parts of the system to achieve good, reliable performance as well as economy. The satellite distribution system used for Jerrold's "Digital Cable Radio" (TM) service was developed with these goals in mind. Developing a satellite distribution system requires selecting data rates, data format, error correction scheme, allowable bit error rate, modulation scheme, and channel bandwidth. Each of these factors is influenced by the others.

"Digital Cable Radio" service distribution requires the distribution of 28 digitally encrypted audio channels in a single satellite transponder channel. Each audio channel consists of a stereo audio pair plus control data. In order to fit all this information into a single satellite transponder bandwidth of 30 MHz, data compression and an efficient scheme of modulation is required. The reason for using a minimum number of transponder channels is cost. Like any scarce resource, the leasing of satellite channels is very expensive. The use of multiple satellite channels would also significantly increase the costs at the CATV head end. Finally, it has to be recognized that it costs money to get high Carrier to Noise ratios on the receiver end. This cost factor is due primarily to the need for larger Satellite Receiver Dishes to obtain higher C/N ratios. The "C" band was chosen because it affords adequate C/N (>12 dB) with the prevailing 3.5 meter dishes and good resistance to fading from rain and clouds. In order to minimize terrestrial interference, the data is transmitted in the center 20 MHz.

SYSTEM

Although this paper is primarily about the Satellite Link itself, the characteristics of the rest of the components of the "Digital Cable Radio" system set much of the link requirements. Therefore I will briefly describe the "Digital Cable Radio" system ("DCR" (TM) for short).

The DCR system consists of the following main blocks:

1 Source Material
2 Encoding and Multiplexing
3 QPSK Modulator
4 Satellite Transmitter
5 Satellite Receiver
6 QPSK Demodulator
7 Head End Transcoder
8 CATV Distribution System
9 DCR Receiver
10 Home Stereo System

The source material consists of CD disks and simulcast channels from premium CATV services. These audio sources go to Dolby (TM) Encoders which use adaptive delta modulation to maintain CD quality audio (95 dB Dynamic range, 20 Hz to 20 KHz response) with a data rate of 294 K bits per second per stereo pair.

Forward error correction is used to increase the corrected error rate by 3 orders of magnitude (from 1E-3 to 1E-6). This involves adding additional bits to the data stream. This plus the encryption and the additional data brings the channel data rate to 694 K bits per second. 28 Channels plus framing and sync bits gives a net data rate of 29 M bits per second. The use of error correction allows for a higher tolerable Bit Error Rate at the Downlink and thus a lower required C/N at the Downlink. Listening tests have indicated that in this format, a corrected Bit Error Rate (BER) of 1E-6 is imperceptible from the original CD. Thus, an uncorrected BER of 1E-3 is the requirement for the Link.

The QPSK Modulator is fed by two 14.5 M bits per second inputs (each the equivalent of 14 Audio Channels) into its "I" and "Q" data inputs. The QPSK Modulator produces a Quadrature Phase Shift Keyed (QPSK) signal on a 70 MHz carrier. This IF signal now contains the 29 M bit/s data stream in a bandwidth of 20 MHz. The QPSK modulator feeds the satellite uplink chain.

The Satellite relays the RF signal back down to the Downlink site. The receiver tunes to the RF signal, down converts to 70 MHz, AGC's the signal amplitude, and AFT's the output frequency.

In the Transcoder frame, the QPSK Demodulator recovers the original data stream and the data clock from the 70 MHz QPSK IF input. These signals are fed to the Processor and Channel Transmitters. The processor controls the Channel Transmitters. The Channel Transmitters pick off their individual channel data and modulate an individual CATV RF output channel (typically in the FM band). These individual channels (at different frequencies) are summed for distribution through the CATV System to the home DCR Receiver.

The DCR Receiver tunes to the desired channel and demodulates the RF to recover the channel data stream. Then, the channel data stream is decrypted and converted to audio. This audio output drives the subscriber's stereo and speakers.

QPSK MODULATOR

Differential QPSK Modulation encodes the data stream as phase changes to the carrier. For example, if both the I and Q data inputs were all zeros, then there would be no phase changes and a bare carrier would result. If both I and Q data inputs were all ones, then both would change every data period. The I and Q data is first differentially encoded so that the differential QPSK demodulator will correctly demodulate the data. Then, pre-emphasis is applied to the I and Q signals. The purpose of the pre-emphasis is to correct for the spectrum shape of rectangular random data (rolls off) and thus to "flatten" the resulting spectrum in order to optimize the transmitted signal energy. The demodulator has a corresponding roll-off filter to equalize the response. Then a 70 MHz carrier is QAM modulated by the differentially encoded and pre-emphasized I and Q signals. Next, the QPSK signal is band limited in a SAW filter and amplified to +3 dBm output level.

The reasons that Differential QPSK was chosen are that it is bandwidth efficient, can deliver less than 1E-3 BER for 12 dB C/N, is robust (tolerates compression and limiting), and can be demodulated in a cost effective manner.

SATELLITE RECEIVER

The main purpose of the Satellite Receiver is to provide amplification and frequency down conversion of the signal from the Satellite. The output of the Satellite Receiver is 70 MHz at 0 dBm. The tuner down converts to 130 MHz, and then this is down converted to 70 MHz. The second down conversion allows for AFT so that the final (most narrow) SAW filter on the QPSK Demodulator is centered on the IF signal. This allows for some drift and error in the LNB at the antenna. The AGC holds the signal amplitude constant so the QPSK Demodulator operates optimally. An AUX input is provided for a 70 MHz input from an existing LNA installation.

QPSK DEMODULATOR

The QPSK demodulator utilizes delay type differential QPSK demodulation. The result is relative design simplicity and virtual immunity to incidental phase noise. First the 70 MHz IF input is bandpass filtered and then mixed down to 29 MHz. The demodulation takes place at an IF frequency of 29 MHz. The demodulator also provides for AFT. This AFT mainly corrects for any slight drift or error in the delay lines. The detected I and Q signals are low pass filtered in a filter which also complements the pre-emphasis in the QPSK Modulator. Then, the data clock is recovered from the detected I and Q. This recovered data clock is then used to sample the detected I and Q to produce the recovered I and Q data.

RESULTS

Testing of uncorrected Bit Error Rate verses Carrier to noise has confirmed results approaching theoretical for C/N in the region of 12 dB. It has been shown that for C/N of 12 dB the uncorrected BER is less than 1E-3 and the corrected BER is less than 1E-6.

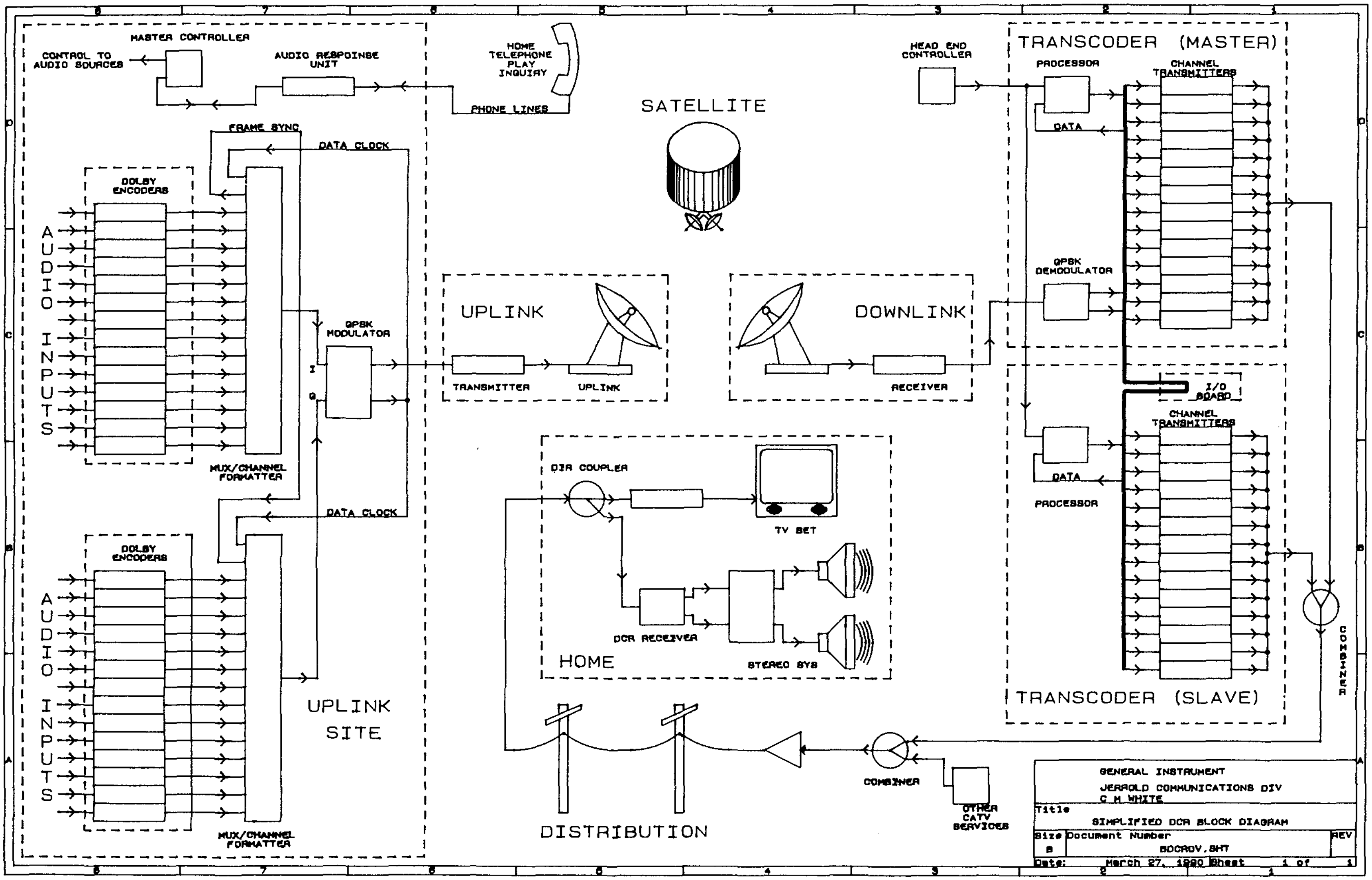
SUMMARY

By the careful choice of data coding, forward error correction, modulation/demodulatiom scheme, and implementation it is possible to distribute 28 stereo audio channels over a satellite link while maintaining quality levels equivalent to the CD source. And, it is possible to do so in an affordable fashion.

TRADEMARKS

"Dolby" is a registered trademark of Dolby Laboratories.

"Digital Cable Radio" and "DCR" are registered trademarks of General Instrument Corporation, Jerrold Communications Division.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CONTROL TO AUDIO SOURCES
AUDIO RESPONSE UNIT
HOME TELEPHONE PLAY INQUIRY
PHONE LINES
SATELLITE
HEAD END CONTROLLER
TRANSCODER (MASTER)
PROCESSOR
CHANNEL TRANSMITTERS
DATA
FRAME SYNC
DATA CLOCK
DOLBY ENCODERS
AUDIO INPUTS
QPSK MODULATOR
I
Q
MUX/CHANNEL FORMATTER
UPLINK
TRANSMITTER
UPLINK
DOWNLINK
RECEIVER
QPSK DEMODULATOR
I/O BOARD
CHANNEL TRANSMITTERS
DATA
PROCESSOR
DIR COUPLER
TV SET
DCR RECEIVER
STEREO SYS
HOME
DATA CLOCK
DOLBY ENCODERS
AUDIO INPUTS
MUX/CHANNEL FORMATTER
UPLINK SITE
COMBINER
TRANSCODER (SLAVE)
DISTRIBUTION
COMBINER
OTHER CATV SERVICES
GENERAL INSTRUMENT
JERROLD COMMUNICATIONS DIV
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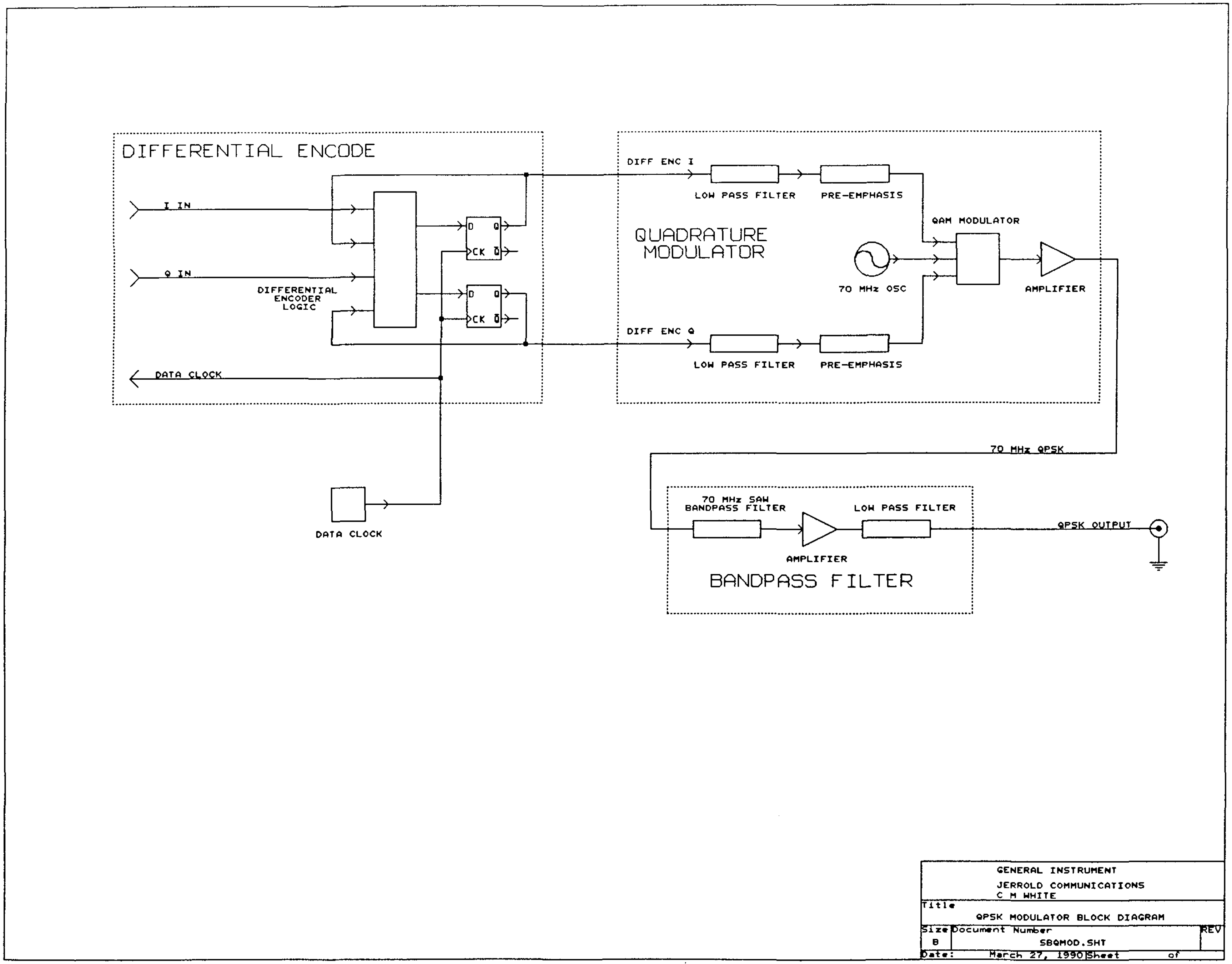
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Q IN
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D Q
CK Q̄
DATA CLOCK
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LOW PASS FILTER
PRE-EMPHASIS
QUADRATURE MODULATOR
QAM MODULATOR
70 MHz OSC
AMPLIFIER
70 MHz QPSK
70 MHz SAW BANDPASS FILTER
AMPLIFIER
LOW PASS FILTER
BANDPASS FILTER
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GENERAL INSTRUMENT
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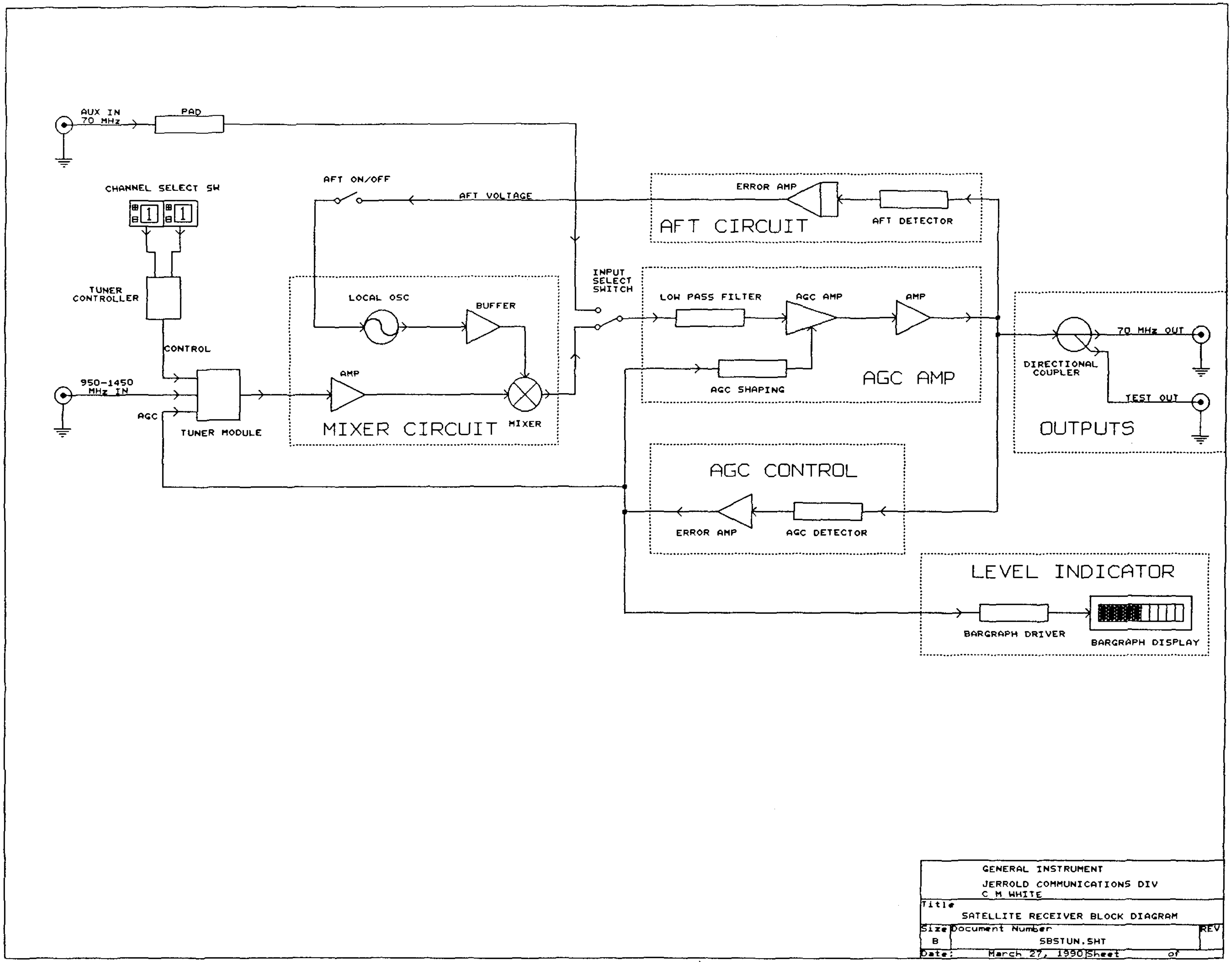
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AFT DETECTOR
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BUFFER
INPUT SELECT SWITCH
LOW PASS FILTER
AGC AMP
AMP
CONTROL
950-1450 MHz IN
AGC
TUNER MODULE
AMP
MIXER CIRCUIT
MIXER
AGC SHAPING
AGC AMP
70 MHz OUT
DIRECTIONAL COUPLER
TEST OUT
OUTPUTS
AGC CONTROL
ERROR AMP
AGC DETECTOR
LEVEL INDICATOR
BARGRAPH DRIVER
BARGRAPH DISPLAY
GENERAL INSTRUMENT
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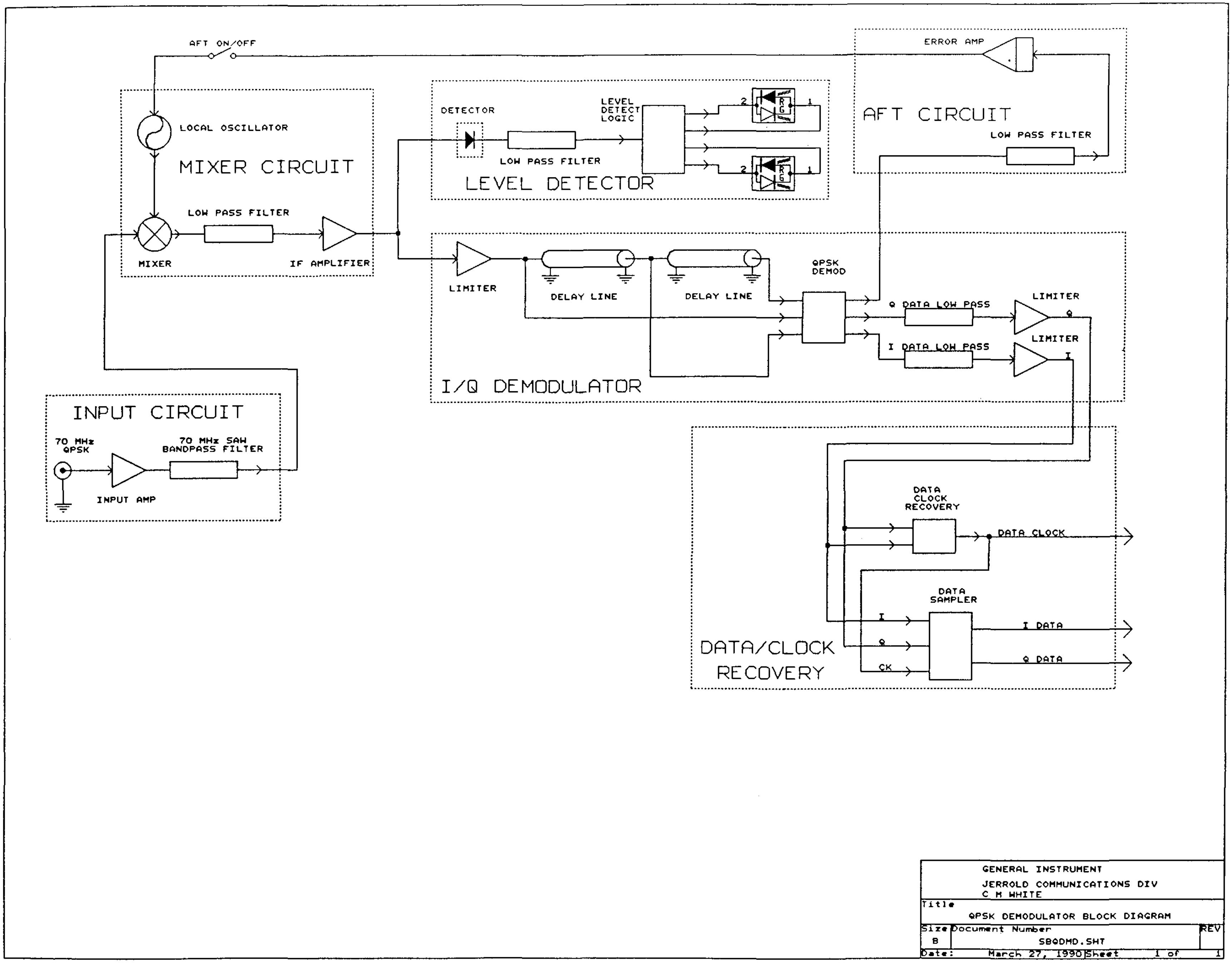
AFT ON/OFF
ERROR AMP
AFT CIRCUIT
LOW PASS FILTER
LOCAL OSCILLATOR
MIXER CIRCUIT
LOW PASS FILTER
MIXER
IF AMPLIFIER
DETECTOR
LEVEL DETECT LOGIC
LOW PASS FILTER
LEVEL DETECTOR
LIMITER
DELAY LINE
DELAY LINE
QPSK DEMOD
Q DATA LOW PASS
LIMITER
Q
I DATA LOW PASS
LIMITER
I
I/Q DEMODULATOR
INPUT CIRCUIT
70 MHz QPSK
70 MHz SAW BANDPASS FILTER
INPUT AMP
DATA CLOCK RECOVERY
DATA CLOCK
DATA SAMPLER
I
Q
CK
I DATA
Q DATA
DATA/CLOCK RECOVERY
GENERAL INSTRUMENT
JERROLD COMMUNICATIONS DIV
C M WHITE
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Size
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