A SATELLITE SIGNAL RECOGNITION SYSTEM

by

Eric A. Oiesen

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APPROVED:

T. Pratt, Chairman

M. J. Feuerstein

B. D. Woerner

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Timothy Pratt, Committee Chairman

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(ABSTRACT)

Geosynchronous communications satellites provide a wide variety of services. They carry wideband signals, such as television, and narrowband signals, such as business data networks. This paper describes a signal recognition system for the narrowband signals found on Ku-band satellites. Using readily available equipment, it saves observed signals which are later processed into an observation report. Observed signals are labeled using a decision tree, which is a pattern recognition technique. Each observation report also includes center frequency, bandwidth, and carrier-to-noise ratio. This paper presents the design and implementation of the signal recognition system. Results from the system are included.

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Chapter 1 - Introduction

Geosynchronous communications satellites provide a wide variety of services. With a clear view of North America, domestic communications satellites can broadcast to any part of the United States. For example, the networks found on cable television use these satellites to broadcast programs to a nationwide audience. News organizations can link remote news gathering trucks with centralized production facilities. Domestic communications satellites are used for more than just television. Private satellite networks provide businesses with two-way communication between a home office and stores scattered over the US, for example.

Television and business networks are just two examples of satellite traffic. The domestic communications satellites function as radio repeaters. Each satellite's repeater capacity is divided into channels. Each channel corresponds to an individual radio repeater in the satellite called a transponder. Commercial satellites operate on two frequency bands: C and Ku. Most television traffic is carried on C-band satellites. The newer Ku-band satellites carry a mix of television and other services, such as business data networks.

Television signals usually require the capacity of an entire transponder. Most other users, such as business networks, use a small fraction of a transponder's capacity. As a result, many users can occupy one transponder. Specific frequency listings describing the users' frequency allocation are not readily available.

If traffic information for the transponders which carry narrowband signals is desired, then a monitoring system is necessary. Using a satellite TVRO (TV Receive Only) system and a spectrum analyzer, a trained human observer requires a few hours to catalog the contents of a single data transponder. Each Ku-band satellite may have several data transponders. In addition to the tedium of performing such an extended observation, a human observer can't easily record the signals viewed for later reference.

This paper describes a satellite transponder signal recognition system that was built from readily available hardware. The system saves observed signals which are later processed into an observation report. The recognition software operates on spectra magnitude provided by a spectrum analyzer; phase information is unavailable from a spectrum analyzer. Traditional signal recognition methods use phase and magnitude information [21]. With only magnitude information, the signal recognition problem becomes a pattern recognition problem.

The observed signals are labeled using a decision tree, a pattern recognition technique. Each observation report also includes signal center frequency, bandwidth, and carrier-to-noise ratio. The system uses a satellite TVRO system, spectrum analyzer, personal computer, and recognition software written by the author.

This paper presents background information in satellite communications and pattern recognition pertinent to the project. The system hardware and software are presented, with details of a custom video sampler board used to interface the spectrum analyzer with the computer. Several examples of observed signals and program output are provided and explained.

Chapter 2 - Satellite Communications Background

2.0 - Chapter Summary

The signal recognition system uses pattern recognition to solve a satellite communications problem. Chapter 2 provides a brief satellite communications background that includes information regarding domestic commercial satellites and signals that they broadcast. Chapter 3 provides a brief pattern recognition background.

Graphs are included to illustrate several satellite signal examples. The author captured all of the signals shown using the recognition system described in Chapter 5. The spectrum analyzer settings for these pictures, unless noted otherwise, were 200 kHz per horizontal division, 10 dB per vertical division, and 30 kHz resolution bandwidth.

2.1 - Geostationary Satellites

Objects in a circular orbit at 35,860 km altitude in the equatorial plane have an angular velocity that matches the angular velocity of the Earth's rotation. To an Earthbound observer, these objects appear to remain motionless in the sky. For this reason, this orbit is called the geostationary orbit.

Satellites in Earth orbit perform such diverse tasks as military reconnaissance, land resources surveying, and communications relay. Communications such as television broadcasting require a permanent link between broadcaster and viewer and are better served by geostationary satellites. Geostationary satellites carry a plethora of specialized communications services that include nationwide television and radio feeds, high-speed data links, and private business data networks.

As shown in Figure 2.1.1, communications satellites are radio repeaters in the sky. In block diagram form, a geostationary satellite's function could be represented as a receive antenna, downconverter, linear amplifier, and transmit antenna. A combination of a downconverter and linear amplifier is refered to as a transponder.

Typically, each geostationary satellite is capable of receiving and transmitting on twenty to thirty preset channels. Figure 2.1.2 shows part of the frequency plan for a typical C-band satellite. Each channel corresponds to a transponder. To better utilize the satellite frequency band, adjacent channels on US domestic satellites use orthogonal polarization so that they may overlap in frequency. US domestic satellites use vertical (North-South) and horizontal (East-West) polarization.

For ITU (International Telecommunications Union) Region 2, which includes North and South America,

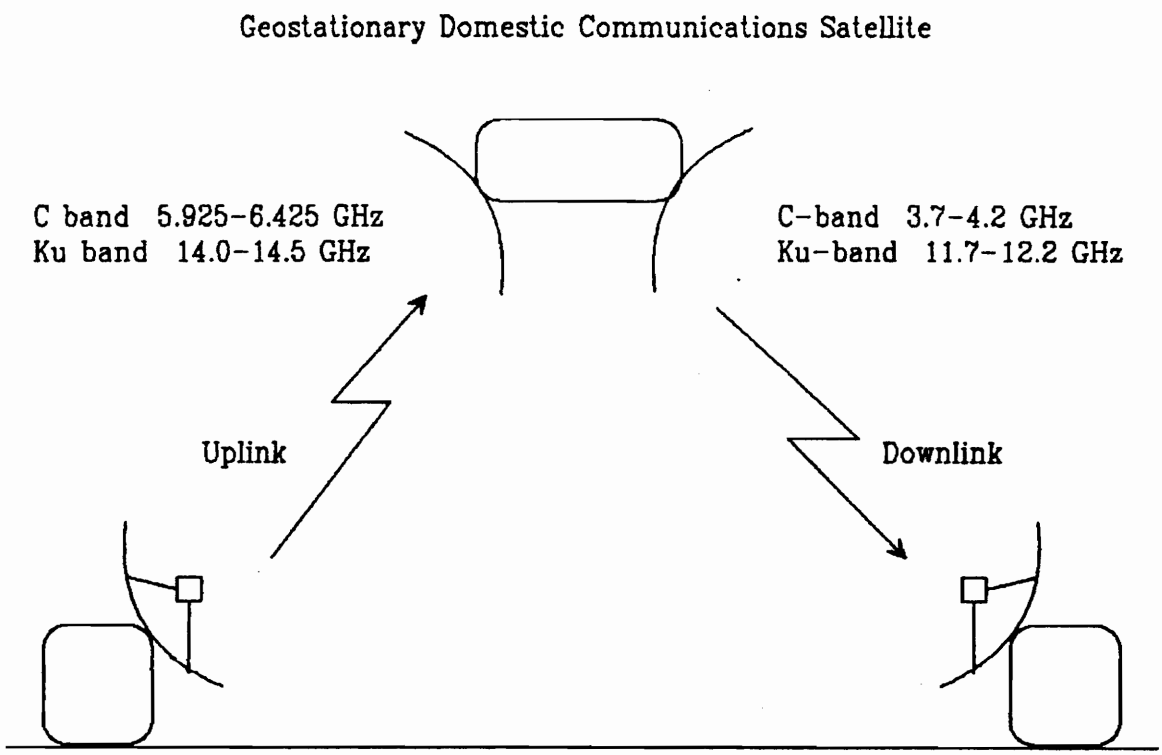
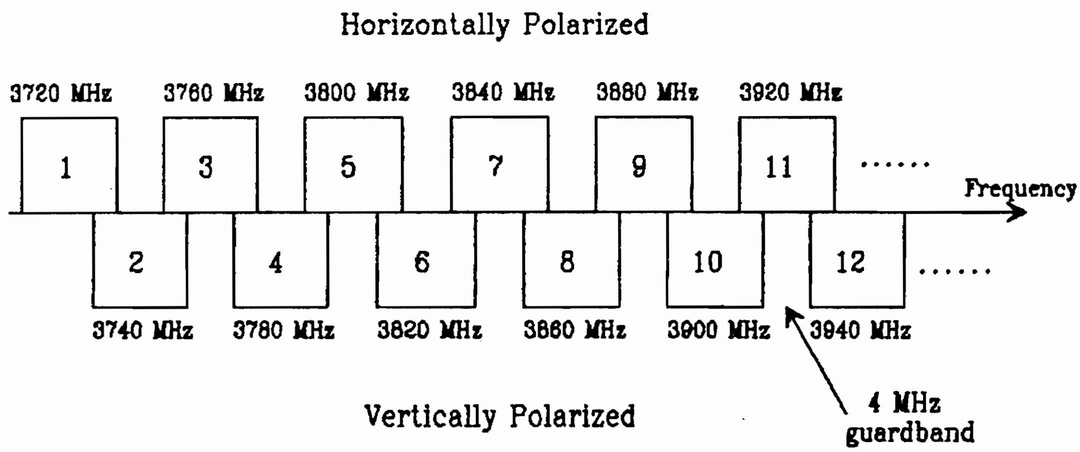


Figure 2.1.1 – A Satellite Link



The channel designations for Galaxy 1, a C-band satellite, are shown. Each channel, which corresponds to a transponder, is 36 MHz wide.

Figure 2.1.2 – Frequency Reuse Using Orthogonal Polarization

commercial geostationary communications satellites operate in two frequency bands: C and Ku. C-band uplinks (ground to satellite) span 5.925 GHz to 6.425 GHz; downlinks (satellite to ground), 3.7 GHz to 4.2 GHz. Ku-band uplinks span 14.0 GHz to 14.5 GHz; downlinks, 11.7 GHz to 12.2 GHz. C-band channel allocation, spacing, and polarization are standardized to 24 channels, 20 MHz spacing, and alternating polarization. Ku-band is not standardized; each satellite's channel structure is unique. **The Satellite Channel Chart** [2], a monthly publication, is an outstanding reference for current satellite positions, frequency listings, and transponder assignments. **The World Satellite Directory 1992** [3] is a compendium of technical and business information related to communications satellites.

2.2 - Satellite Traffic

The first band used for commercial communications satellites occupied a 500 MHz portion of the C-band. The early uses for the new technology included transoceanic and transcontinental telephony and transoceanic television broadcasts. To provide more space for commercial communications satellites, a 500 MHz portion of the Ku-band was officially allocated to satellite use in 1979.

The new Ku satellite band offered unspoiled frequency space, unlike C-band satellites that shared the same band with terrestrial microwave links. To prevent interference, the flux density at the Earth's surface was legally restricted for C-band satellites. The Ku satellite band did not have similar limitations, which allowed the use of a smaller receive dish. The march of technology produced cheaper, smaller earth station equipment. These factors allowed businesses to operate their own satellite networks, an option that provided them with dedicated data links at a lower cost than dedicated telephone lines. The advent of transcontinental fiber cables moved telephone business off of the satellites, opening more room for cable television, radio feeds, business data networks, and a wide variety of other services.

2.3 - Satellite FM Video

Today, the Ku satellite band is used by a wide variety of signals. Using a spectrum analyzer to view a satellite's downlink, a viewer can quickly pick out broadband FM video, which is used for television broadcasts. Figure 2.3.1 displays FM video spectra from GE Satcom K2, a Ku-band satellite. The spectrum analyzer settings were 50 MHz per horizontal division, 10 dB per

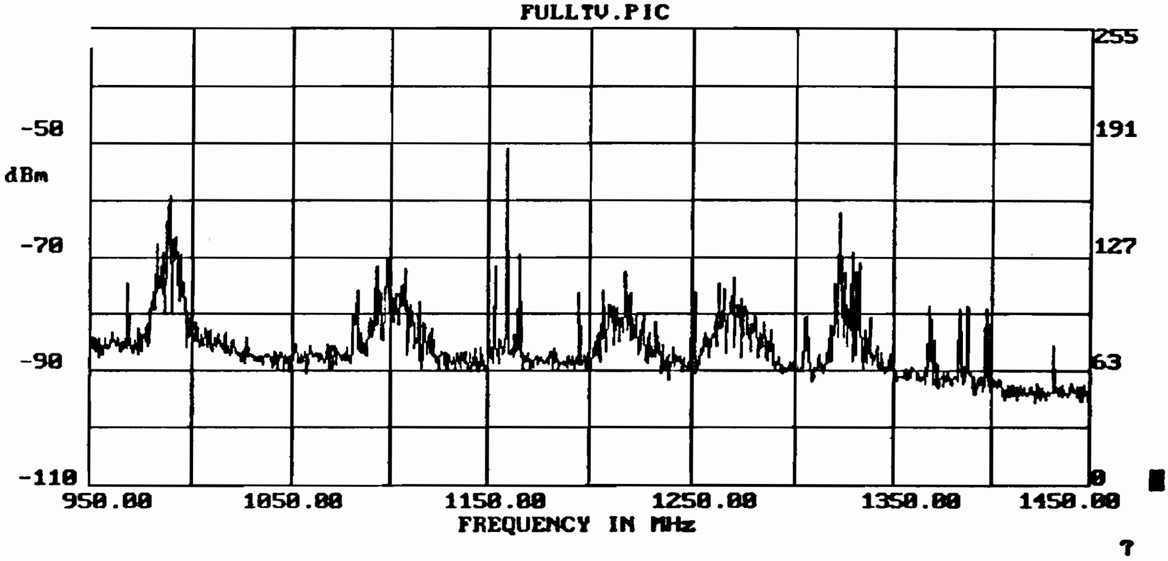


Figure 2.3.1 - FM Video Spectra
RESBW = 5 MHz   SPAN/DIV = 50 MHz

vertical division, and 5 MHz resolution bandwidth. The sharp spike at approximately 1150 MHz is a video carrier.

TV broadcasters use satellites to distribute finished programming and to gather news and sports from remote locations. Video conferencing is another use of FM video. Several scrambling systems provide secure video and audio communications. Satellite video services, such as cable networks and pay-per-view services, also allow relatively small operators to reach a nationwide audience.

FM is a good choice for broadcasting an analog signal in a noisy and power-limited environment that has plenty of bandwidth. The utilization of wideband FM provides a S/N improvement over the received C/N. The S/N improvement ranges from 24 dB for a 17 MHz bandwidth to 38 dB for a 36 MHz bandwidth. The calculation of these results is listed in Appendix 2A. Satellite FM video starts with a 4.2 MHz wide NTSC standard video signal at baseband. NTSC standard video is used in the United States. FM video bandwidths range from 17 MHz for the Ku band Canadian Anik series to the C-band standard of 36 MHz. Most Ku-band services use 25 MHz bandwidths.

The S/N improvement is necessary to provide a watchable picture with the typical TVRO C/N. A link budget for the TVRO system described in Chapter 5 shows that the received C/N for FM video from a strong Ku band satellite such as GE Satcom K2 is 16.3 dB. The link budget is presented in Appendix 2B. A S/N of 45 dB or greater provides an acceptable picture. Adding the C/N to the FM improvements and subjective weighting for a standard C-band TV signal results in a S/N of 47 dB.

2.4 - VSAT

A typical Ku band satellite transponder may carry one or two FM video signals. It can also carry many relatively narrow signals. This kind of transponder traffic looks like noise approximately 15 dB above the noise floor when the entire transponder is viewed on a spectrum analyzer. A narrower spectrum analyzer span will reveal a multitude of narrow signals.

VSAT (Very Small Aperture Terminal) networks are frequently found on Ku band satellites. Businesses such as Chrysler, Wal-Mart, and K-Mart use VSAT networks to link individual stores to a central hub. Primary uses for VSAT networks include the transfer of inventory information, validation of credit card information, and videoconferencing. Satellite Communications' **1991 Private Networks Directory** [7] lists a few hundred VSAT networks.

A VSAT network is composed of a central hub and many users in a star network. The hub station is a medium size Earth station with an antenna and transmitter sufficient to provide a strong signal to the users. The users, as implied in the name VSAT, use small antennas that are 1.2m to 1.8m in diameter with a 1-3 W transmit amplifier.

Two links exist: the hub-to-user (outbound) link and user-to-hub (inbound) link. Forward error correction codes such as convolutional coding using rate = 1/2 and a constraint length of seven (K=7) are used to improve the bit error rate [20]. The outbound link constantly provides the users with data and network control information using a TDM (Time Division Multiplex) format signal. Each user listens for its unique address; it then knows that the data following the address is intended for that particular station. The outbound link usually operates at a data rate between 56 kbps and 512 kbps using BPSK modulation [20]. With the given coding rate, these data rates result in RF bandwidths ranging from 162 kHz to 1.485 MHz. Refer to Appendix 2C for the RF bandwidth calculations.

The inbound link operates only when the user has information to transmit; therefore, the link is bursty. On a spectrum analyzer, inbound signals can be seen bouncing up and down from frame to frame as in Figure 2.4.1 and Figure 2.4.2. The inbound link usually operates at a data rate less than 128 kbps using BPSK modulation. This corresponds to a RF bandwidth of less than 370 kHz. FDMA (Frequency Division Multiple Access) and contention-based

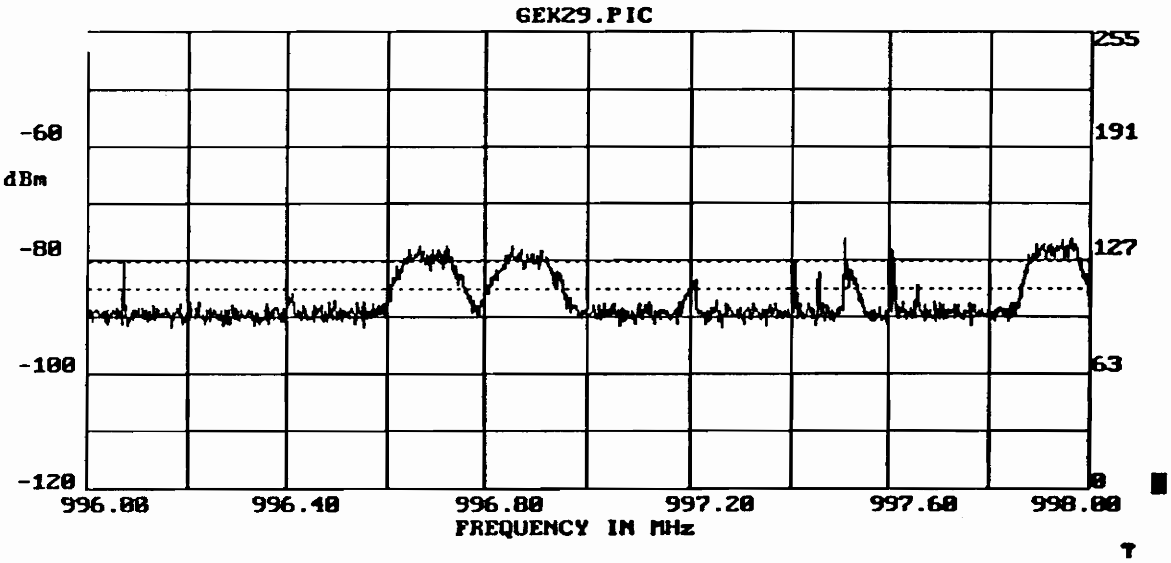


Figure 2.4.1 - PSK and VSAT Signals (Sweep 1)

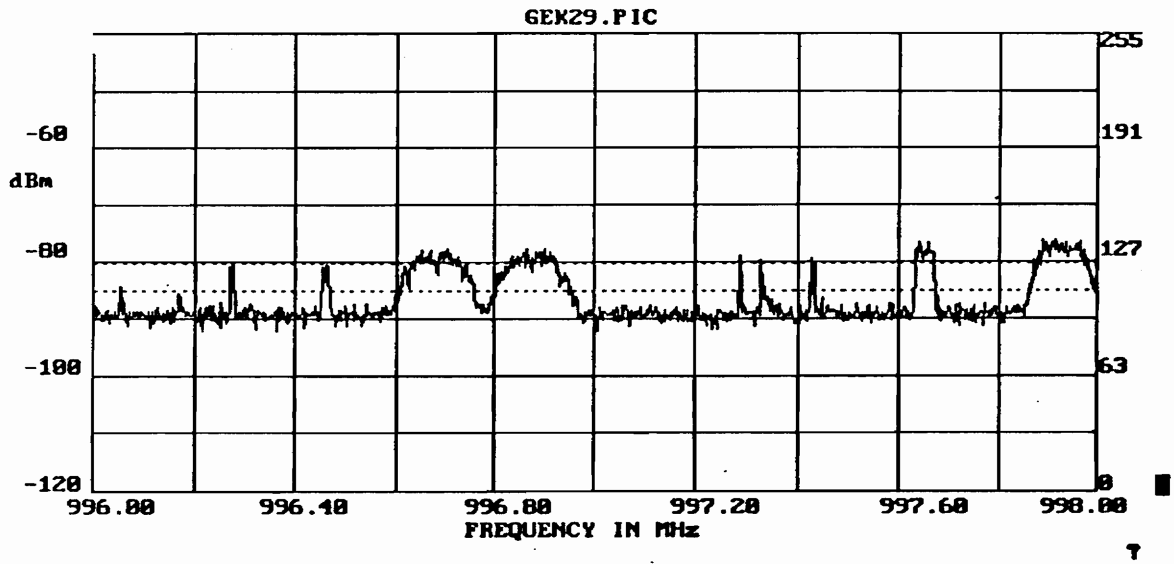


Figure 2.4.2 - PSK and VSAT Signals (Sweep 2)

TDMA (Time Division Multiple Access) are two multiple access systems by which users are allocated transmit frequencies [10].

In a FDMA system, users are assigned a fixed transmit frequency. The user transmits whenever it has data. This system makes poor use of the available transmit frequencies if the traffic is light.

In a contention-based TDMA system, users randomly transmit packets of data. If the hub correctly receives the packet, it sends an acknowledgement. If the user does not receive the acknowledgement within a certain period of time, the user will re-transmit the packet. There are many variations on this basic idea that involve varying levels of hub traffic management.

2.5 - Voice Signals

A common method of distributing radio feeds is by SCPC-FM (Single Channel Per Carrier). A SCPC-FM signal is shown in the middle of Figure 2.5.1. A FM signal with a 60 kHz bandwidth is usually used. FM is a good choice for voice broadcast for the same reasons that it is a good choice for television broadcasts. DATS (Digital Audio Transmission Standard) is a new digital standard for CD quality satellite sound transmissions. DATS and SCPC-FM are found primarily on C-band satellites.

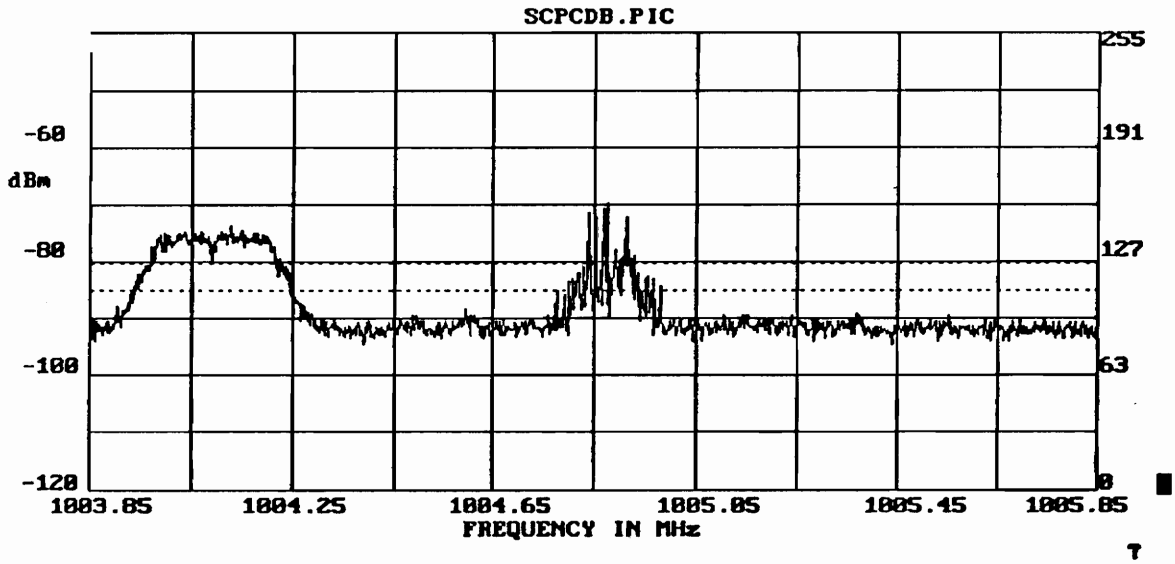


Figure 2.5.1 - Single Channel per Carrier FM

2.6 - Data Signals

Most of the information in modern communication systems is digital regardless of the original source. Several modulation formats are appropriate for broadcasting digital data. The most common satellite format is PSK (Phase Shift Keying) [8]. BPSK (Binary Phase Shift Keying) uses two phase states to represent a 1 or 0. QPSK (Quadrature Phase Shift Keying) uses four phase states to represent four combinations of two bits. A QPSK modulator is equivalent to two BPSK modulators with carriers that are in quadrature. A typical PSK signal is shown in Figure 2.5.1 at approximately 1004 MHz.

Transmitting unfiltered digital signals would result in an infinite bandwidth signal. The Fourier transform of a square wave is an infinite series of odd harmonics. The Fourier series of a pulse train results in a sin x/x spectrum that extends to infinite frequency. Due to the bandwidth limitations of the real world, a digital signal must be filtered in a way that will reduce its bandwidth but allow error-free decoding. The Nyquist zero ISI (Intersymbol Interference) criterion provides a method which allows transmission of digital signals in a finite bandwidth without ISI. The basic idea is to use a filter with an impulse response which is zero at all sample points except one. An impulse generator can be used to drive this filter, or a NRZ waveform with an equalizer.

The Nyquist zero ISI method uses an impulse generator as a data source to drive a raised cosine filter. The impulse response of the raised cosine filter is a damped sin x/x signal with zero crossings occuring every T_b s. This means that an impulse train would produce a signal that at intervals of T_b s contains energy from one impulse only. If this sequence is sampled every T_b s, the signal can be decoded without ISI. If the data source isn't an impulse generator, the source must be equalized to be equivalent to an impulse generator for this method to produce zero ISI.

When a NRZ (bipolar Non-Return to Zero) data source drives a PSK modulator, the resulting signal has a sin x/x spectrum. Applying square root raised cosine filtering to meet Nyquist zero ISI requirements reduces the PSK spectrum to its central lobe. An x/sin x equalizer is used to equalize the data source to have approximately the same spectrum as an impulse generator over the bandwidth of the raised cosine filter.

Using a spectrum analyzer which displays only spectral magnitude as the source of information about signals, it appears to be impossible to differentiate QPSK and BPSK signals. A QPSK signal is simply two superimposed BPSK signals in phase quadrature.

2.7 - Unidentified Signals

Since the available literature does not list specific frequencies for non-entertainment services, the identification of recorded signal types requires prior knowledge of available systems. Without the prior knowledge, positive identification cannot be made. For example, Figure 2.7.1 displays three groups of narrow bandwidth signals. They may be SCPC or a FDMA VSAT system; however, the group envelope is rounded. This suggests that these signals come from a common source.

Figure 2.7.2 shows a series of spikes. If the spectrum analyzer sweep speed is increased, the display indicates a single spike that hops in frequency. A review of the available literature does not indicate frequency hopping to be a common satellite signal format. The signal may be part of a random access system with many terminals.

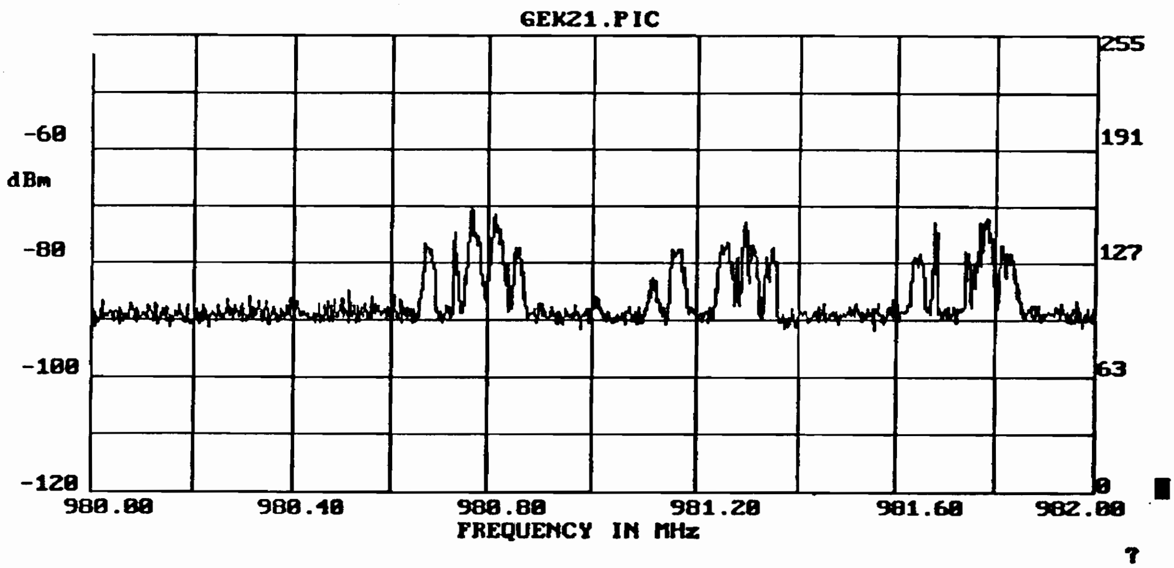


Figure 2.7.1 - Narrowband Signal Groups

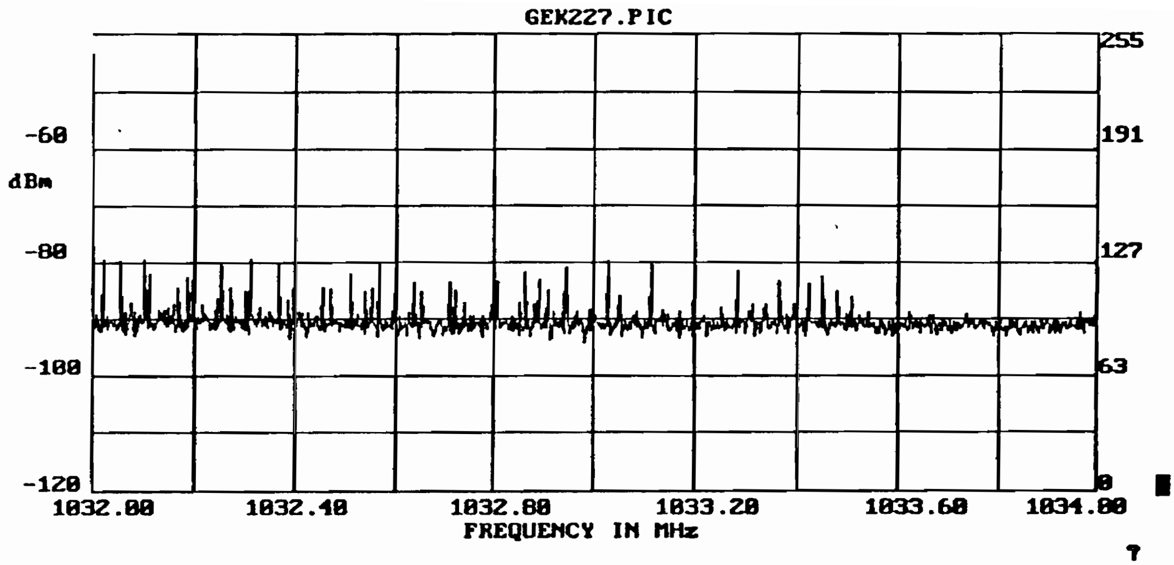


Figure 2.7.2 - Unidentified Signal

2.8 - Signal Recorders

A literature search on the subject of signal recognizers and loggers specifically for satellite communications revealed two references. The first, in COMSAT Technical Review [6], is an article which describes a computer controlled satellite signal monitor. The computer controlled system monitored the satellite signals received at the Andover, Maine earth station. The system consisted of an IBM mainframe, an earth station receiver, receive filters with a range of bandwidths, and a radiometer. The computer's program contained an observation schedule. For each specific signal, the computer used the receive filters and the radiometer output to determine if the signal was on frequency and if it met C/N specifications.

The second reference [5] describes an experimental system used for recognizing constant envelope digitally modulated signals such as PSK signals. The Newman Library at Virginia Tech did not contain this reference but the abstract was available through the Engineering Index database, COMPENDEX 1989. This system used a series of zero crossings to identify constant envelope modulated signals. The system's output included C/N and carrier frequency. The abstract claims that "The obtained simulation results demonstrate that reasonable average probability of correct classification is achievable at C/N equals 15 dB and higher." Considering that many satellite signals, VSAT in particular, are below 15 dB C/N when measured with a TVRO earth station, the direct application of this particular technique to the satellite signal recognition problem may not work. The abstract did not specify the way in which the system was fed information.

Appendix 2A

Equation (5.32) from [8] expresses video S/N as a sum of C/N, FM improvement terms, and subjective weighting:

$$(S/N)_V = (C/N)_i + 1.76 + 10\log(B_{IF}/f_V) + 20\log(f_{PEAK}/f_V) + P + Q \text{ dB}$$

This can be restated as:

S/N = C/N + FM improvement + subjective term

where:

$$\text{FM improvement} = 1.76 + 10\log(B_{IF}/f_V) + 20\log(f_{PEAK}/f_V)$$

subjective term = P + Q

Definition of Terms:

$(S/N)_V$ - Output signal-to-noise ratio
$(C/N)_i$ - Input carrier-to-noise ratio
B_{IF} - Bandwidth of the receiver IF
f_V - Highest frequency of the baseband video signal
f_{PEAK} - Peak frequency deviation

P - Preemphasis factor. The preemphasis factor accounts for an improvement produced by giving the baseband signal a high frequency boost and then reducing receiver noise with a low-pass filter.

Q - Weighting factor. The weighting factor is a subjective factor that adjusts the physical S/N to the perceived S/N. Because some noise is more bothersome to a viewer, the measured S/N, in terms of the ratio of signal power to rms noise power, may not describe the S/N perceived by the viewer. By analogy, two cars may have a measured noise level of 70 dBa (dB acoustic). Car 1's noise is due to the swish of tires and the whoosh of air passing over the car. Car 2's noise is due to the swish of tires, the whoosh of air, and a very annoying squeak. A panel of listeners would find Car 2 louder than Car 1 due to the annoying squeak and therefore assign a higher subjective noise level to Car 2.

Note: It is common to lump P and Q together. 18dB is an estimate typically used for P+Q [8].

Using Table 3.55 in [10]:

BW_{IF}	f_V	f_{PEAK}	FM imp	FM imp+(P+Q)
36 MHz	4.5 MHz	13.5 MHz	20dB	38dB
27	4.5	7.5	13	31
25	4.5	8.0	14	32
17	4.5	4.0	6	24

Appendix 2B
The link budget was calculated using Mathcad 3.0.

Description of Link Budget Variables:

T_g - Physical Temperature (ambient)
T_{lnb} - LNB Noise Temperature
B - Bandwidth of the TVRO IF
k - Boltzmann's Constant
c - speed of light
f - receive frequency
EIRP - Effective Isotropic Radiated Power
L_a - atmospheric loss
L_{slop} - polarization mismatch and pointing loss
LAT - observer's latitude
$LONG_{gnd}$ - observer's longitude
$LONG_{sat}$ - satellite's longitude
epsilon - antenna efficiency
dia_{dish} - receive antenna diameter
e_{feed} - feed efficiency
G_{lnb} - LNB gain
Cablelength - length of coax run from antenna to receiver
Loss - cable loss in dB per 10 m
d - range from observer to satellite
L_p - free space loss
G_r - gain of the receive antenna
P_{ant} - received power at antenna terminals
G_{cable} - cable gain
P_{TVRO} - receive power at TVRO unit
T_{space} - noise temperature of sky
T_{ant} - antenna noise temperature
T_{cable} - cable noise temperature
T_{sys} - system noise temperature
Noise - noise power at antenna terminals
CN - carrier to noise ratio

Calculation of Link Budget for Typical Ku Band Satellite Using Satcom TVRO System

Variables for Calculation:

$T_g := 270$ $\quad T_{lnb} := 225$ $\quad B := 27\cdot10^{6}$ $\quad k := 1.38\cdot10^{-23}$ $\quad c := 3\cdot10^{8}$ $\quad f := 11.95\cdot10^{9}$

$EIRP := 45$ $\quad L_a := 1$ $\quad L_{slop} := 1$ Enter losses in dB

$LAT := 37.229$ $\quad LONG_{gnd} := 80.438$ $\quad LONG_{sat} := 81$

$\varepsilon := .5766$ $\quad dia_{dish} := 2.8$ $\quad e_{feed} := .9$

$G_{lnb} := 50$ $\quad Cablelength := 45$ $\quad Loss := 2.625$ (RG-6 loss in dB per 10m)

Calculate range from satellite to point on Earth:

$$\gamma := acos\left[cos(LAT)\cdot cos\left[LONG_{sat} - LONG_{gnd}\right]\right]$$

$$d := 42242000\cdot(1.02274 - .301596\cdot cos(\gamma))^{.5}$$

$\gamma = 0.716066$ $\qquad d = 3.76693\cdot10^{7}$

Calculate path loss:

$$L_p := 20\cdot log\left[\frac{(4\cdot\pi\cdot d)}{\left[\frac{c}{f}\right]}\right]$$

$L_p = 205.50888$

Calculate receiving antenna gain:

$$G_r := 10\cdot log\left[\varepsilon\cdot\left[4\cdot\pi\cdot\frac{\left[\pi\cdot\left[\frac{dia_{dish}}{2}\right]^{2}\right]}{\left[\frac{c}{f}\right]^{2}}\right]\right]$$

$G_r = 48.499837$

Calculate received power at antenna terminals:

$P_{ant} := EIRP + G_r - L_p - L_{slop} - L_a$ All terms are dB or dBW

$P_{ant} = -114.009043$

Calculate coax cable loss:

$$G_{cable} := \frac{(Cablelength \cdot Loss)}{-10}$$

$$G_{cable} = -11.8125$$

Loss is stated in dB per 10 meters. Gcable is in dB.

Calculate received power at TVRO receiver input:

$$P_{TVRO} := P_{ant} + G_{lnb} + G_{cable}$$

$$P_{TVRO} = -75.821543$$

Summary of received signal power:

$P_{ant} = -114.009043$ $\quad$ $P_{TVRO} = -75.821543$ $\quad$ values in dBW

To calculate the system noise power, the system noise temperature must be calculated:

$$T_{space} := 2.6 \cdot 10^{7} \cdot \left[\frac{f}{10^{6}}\right]^{-2}$$

from P. Panter, Communications Systems Design, McGraw Hill, 1972, p.168.

$$T_{ant} := e_{feed} \cdot T_{space} + \left[1 - e_{feed}\right] \cdot T_{g}$$

$T_{ant} = 27.163863$ $\quad$ $T_{space} = 0.18207$

Calculate cable noise temperature:

$$T_{cable} := 290 \cdot \left[1 - 10^{\left[.1 \cdot G_{cable}\right]}\right]$$

$$T_{cable} = 270.894958$$

Calculate the system noise temperature:

$$T_{sys} := \left[T_{ant} + T_{lnb} + \frac{T_{cable}}{10^{\left[.1 \cdot G_{lnb}\right]}}\right]$$

$$T_{sys} = 252.166572$$

$$Noise := -228.6 + 10 \cdot \log(B) + 10 \cdot \log\left[T_{sys}\right]$$

$$Noise = -130.269487$$

$$CN := P_{ant} - Noise$$

$$CN = 16.260444$$

Appendix 2C

RF Bandwidth Calculations: $BW_{RF} = R_b(1 + a)$

In the case of QPSK, R_s is substituted for R_b.

BW_{RF} - RF Bandwidth
R_b - bit rate
R_s - symbol rate
a - shape factor for raised cosine filter

a is the shape factor for raised cosine filters. Typically, a is between 0.2 and 0.5 in satellite PSK systems. For the computations presented in section 2.4, a=.45 was used.

Chapter 3 - Pattern Recognition

3.0 - Chapter Summary

This paper describes a satellite transponder signal recognition system. The system saves observed signals which are later processed into an observation report. The recognition system operates on spectra magnitude provided by a spectrum analyzer; phase information is unavailable from a spectrum analyzer. Traditional signal recognition methods use phase and magnitude information [21]. With only magnitude information, the signal recognition problem becomes a pattern recognition problem. Figure 3.0.1 depicts a generic pattern recognizer.

The feature extractor performs the first step in the recognition process. To make recognition a tractable problem, a pattern recognizer bases its decision on a data set that characterizes the pattern in question. The data set is chosen to be large enough to allow accurate recognition but small enough to be manageable.

The analyzer performs the second step in the recognition process. The analyzer embodies the rules that translate the data set into a recognition. Statistical and syntactical pattern recognition are two traditional pattern recognition methods. More recently, AI (Artificial Intelligence) models, such as the decision

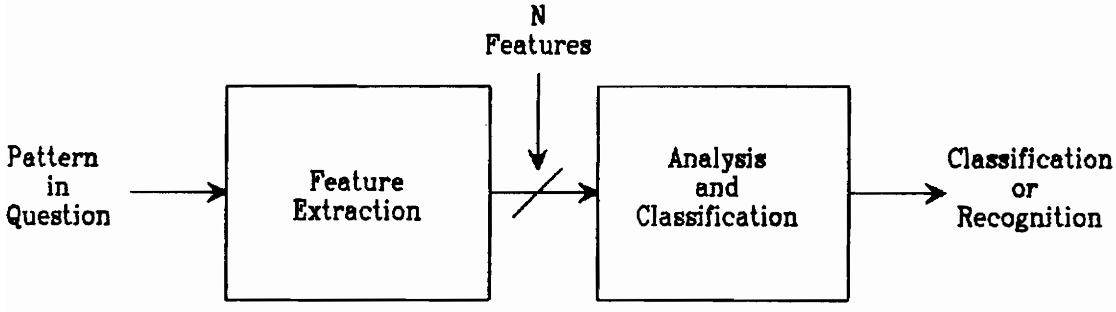


Figure 3.0.1 – A Basic Pattern Recognizer

tree model, have been used for pattern recognition. Section 3.1 presents several formal pattern recognition methods.

Each pattern recognition method requires a certain type of data. The contents of the data set limit the choices of the pattern recognition method. Section 3.2 presents the application of the AI decision tree method to the problem of recognizing satellite signal spectra.

3.1 - Pattern Recognition - Formal Methods

This section provides a brief synopsis of several pattern recognition methods considered for this project. The reader who desires greater depth in the field of pattern recognition is directed to [11,12].

Template matching is one of the simplest forms of pattern recognition. Some bank check readers use this technique [12]. This method dispenses with the first block of Figure 3.0.1. The analyzer contains a set of templates against which the pattern in question is compared. The template that provides the closest match provides a recognition.

Statistical pattern recognition is a traditional pattern recognition technique that has been used for such things as character recognition, medical diagnosis, automatic inspection, and speaker identification [11]. The feature extractor breaks the pattern in question down into a list of features. The feature set for a person, for example, might include height, weight, and sex. The feature set, a vector, contains features with known statistical distributions. The analyzer multiplies the feature set with a weight vector. The weight vector embodies the features' statistical distributions. The resulting scalar score is compared to the available recognition catagories and a recognition is produced.

Syntactical pattern recognition is another traditional pattern recognition technique. It has found application in waveform analysis, ECG interpretation, speech recognition, and fingerprint classification [12] to name a few examples. The feature extractor parses the pattern in question into primitive components. The complete set of primitive components can be arranged to describe any pattern. A Boolean statement is constructed that relates the primitives together. This statement is then compared to statements which describe known patterns. A match constitutes a recognition.

The decision tree method is an artificial intelligence method for pattern recognition. It has been used for such things as remote sensing, blood cell classification, and sonar classification [11]. Its structure is similar to the game '20 Questions'. A decision tree can be used by itself to produce recognitions or it can be used to reduce a complex problem into subcomponents amenable to other pattern recognition methods.

The feature extractor provides a feature set. The analyzer poses yes or no questions pertaining to the features. The questions start with vague qualities and progress to more refined qualities. The result of the question sequence should be a successful pattern recognition. The decision tree can be drawn as a tree which consists of nodes (questions) and branches (answer paths) which connect nodes.

3.2 - Decision Tree and Methodology

The first task in pattern recognition is the selection of a feature set. The feature set should adequately characterize the patterns in question. The features should be easy to obtain and should be unique with respect to each other.

With these brief guidelines in mind, several data transponders on several Ku band satellites were searched using a spectrum analyzer. GE Satcom K2 was most closely searched because it contained a wide variety of signals and it broadcasts a strong signal. Using the results of the search, it seemed that a human observer identified signals based on shape, bandwidth, spacing, and transient behavior. With regard to coding the computer to cull features, it appeared that shape would be the hardest feature and that bandwidth would be the easiest.

A human observer also can demonstrate great flexiblity with respect to scale variance. Changing the spectrum analyzer's scale would essentially make all of the signals look different. To avoid problems with regard to scale variance, 200 kHz per horizontal division, 30 kHz resolution bandwidth and 10 dB per vertical division were chosen. These values seemed to be a good tradeoff between screen sweep times and the ability to see pertinent spectra detail.

After these observations, a pattern recognition method was chosen. The noise and transient behavior of some signals made template matching a poor choice. Signal statistics were not available, so statistical pattern recognition was discarded. The curve fitting routines required to implement syntactical pattern recognition would be time consuming and computationally intensive. Since this could result in a slow system, syntactical pattern recognition was discarded.

As stated before, bandwidth and grouping information were relatively easy to obtain. These features lent themselves to a decision tree pattern recognition method. The decision tree method was also attractive because it is flexible. If new features or feature characteristics were observed, the tree structure could be changed to accomodate them. The details of the implementation of the decision tree are presented in Chapter 4, which also discusses the software design and implementation.

Chapter 4 - Software

4.0 - Chapter Summary

Many of the transponders aboard Ku-band domestic geostationary satellites do not carry television signals. Instead, they carry a diverse selection of narrower bandwidth signals. The recognition system consists of hardware and software for observing, logging, and cataloging these signal spectra. To quickly log and label these signals, a two-part recognition software package was written. This chapter describes the operation and development of the recognition software. Appendix 4A is a user's manual for the software package.

The recognition software consists of two programs that were written in Turbo Basic: OBSERVE.BAS and RECGNIZE.BAS. OBSERVE.BAS accepts and organizes digitized video samples into *.PIC files. RECGNIZE.BAS processes *.PIC files and returns *.DAT files which contain signal statistics and identification. RECGNIZE.BAS also includes utilities for viewing *.DAT and *.PIC files. An operator may easily check a *.DAT file against its corresponding *.PIC file.

RECGNIZE.BAS uses the decision tree method to perform signal recognition. Signals are found using reference level zero crossings. The detected signals are then separated by bandwidth. Wideband signals are given the PSK label. Narrowband signal grouping and narrowband signal transience are used to further separate narrowband signals. The final signal catagories are PSK, VSAT, Narrowband Group (NBND GRP), and Potential Carrier.

4.1 - Program Operation - Observation

OBSERVE.BAS accepts and organizes digitized video samples from the spectrum analyzer into *.PIC files. OBSERVE.BAS also coordinates observation sessions. Appendix 4A is the users manual for OBSERVE.BAS. Once the operator provides the initial start frequency and a root name for the picture and data files, the operator only needs to increment the spectrum analyzer's start frequency upon computer prompt. The operator is given the opportunity to terminate program operation between screen acquisitions.

Each *.PIC file contains two consecutive screen sweeps. Spectra transience is determined by selectively comparing the two sweeps. *.PIC files contain a header that includes start frequency, frequency span per division, resolution bandwidth, amplitude span per division, and the amplitude of the screentop. All data are stored in ASCII format.

4.2 - Program Operation - Signal Cataloging and Recognition

RECGNIZE.BAS uses the decision tree method to catalog signals found in *.PIC files. The decision tree is displayed in Figure 4.3.4 and discussed in Section 4.3. The output from RECGNIZE.BAS is placed in *.DAT files that include center frequency, bandwidth, C/N, and signal label. *.DAT files commence with a header that includes the start frequency, resolution bandwidth, frequency span per division, amplitude span per division, and number of signals in the file. Utilities in RECGNIZE.BAS will display individual *.DAT files and graph individual *.PIC files. An operator may quickly check the results from RECGNIZE.BAS against the original *.PIC file.

Appendix 4A provides user's information. To operate RECGNIZE.BAS, the user provides several pieces of information: the root name of the *.PIC files from an observation session, the root name of the individual output files, and the name of the file that will contain the results for the entire observation session. After providing the number of files that will be accepted, the program autonomously processes the *.PIC files. Once the program is finished, the user may observe individual *.DAT files. The user may also sequentially observe the individual *.PIC files. This utility allows the user to easily check the program's output against the input.

4.3 - Program Development - RECGNIZE.BAS

4.3.1 - Feature Extractor

The feature extractor and the analyzer are not coded as distinct subroutines, but their functions may be represented and described in two separate sections. As shown in Figure 4.3.1, the feature extractor is the first step in pattern recognition. The feature extractor provides the raw material for the decision tree which is located in the analyzer block of the generic pattern recognizer. For this project, the feature extractor detects signals, determines bandwidth, senses groups of signals, and calculates two measures of signal transience. The top of the decision tree starts with a signal; therefore, the feature extractor must find signals first.

Two reference levels are used to find signals (see Figure 4.3.2, Full Size View). Only the first screen sweep is checked for signals. The lowest reference level, called REF, is the signal threshold. Crossing REF, however, does not guarantee that a signal has been found. Noise can cause fluctuations about REF which can provide the two crossings necessary to define a signal (see Figure 4.3.2, Magnified View).

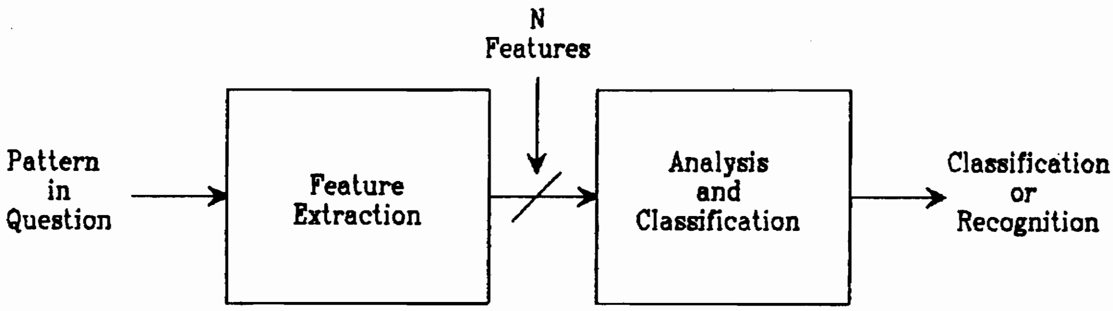


Figure 4.3.1 – A Basic Pattern Recognizer

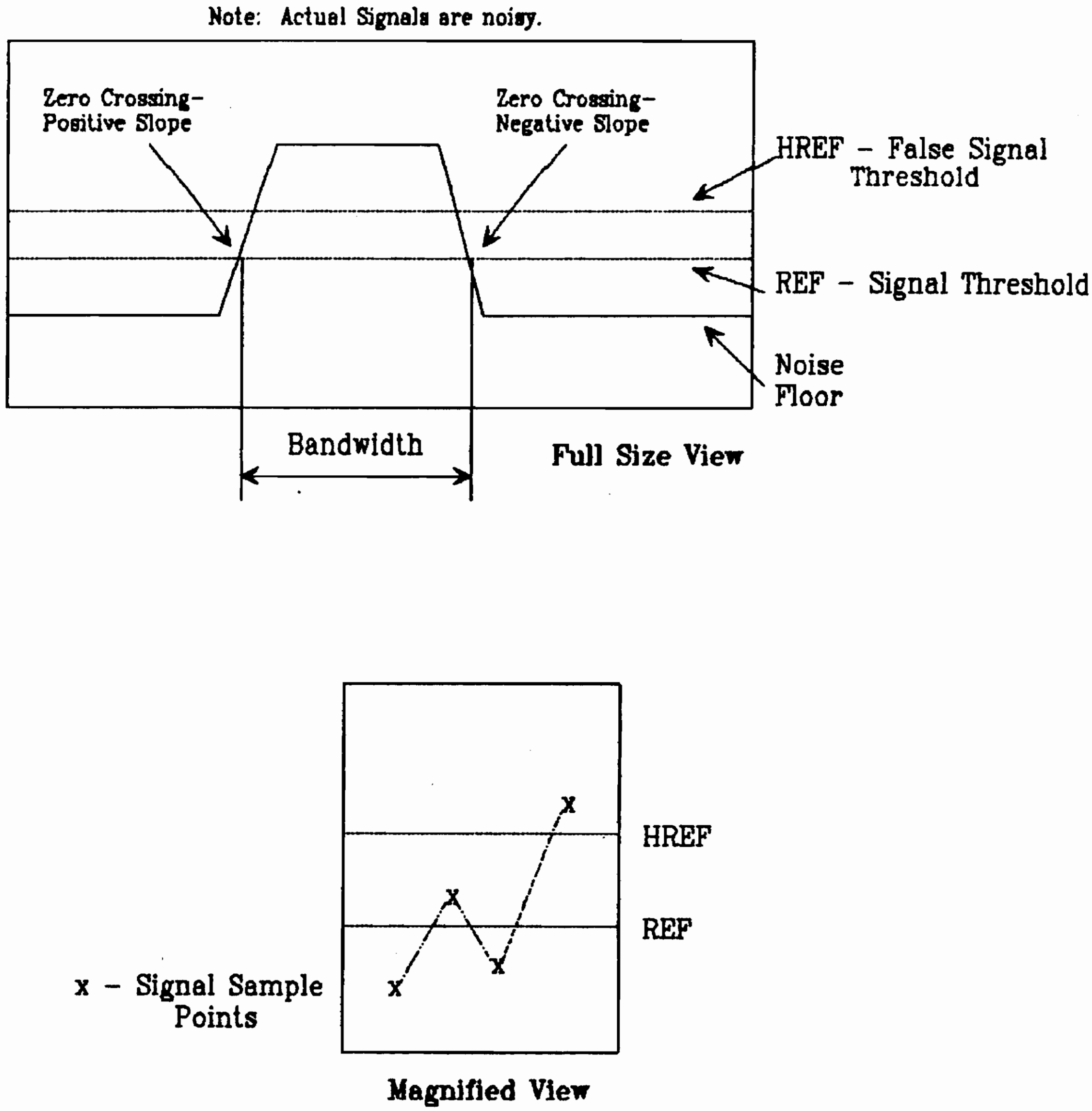


Figure 4.3.2 - Signal Threshold Levels

The second level, HREF, is used to filter out spurious signals such as the one shown in Figure 4.3.2 Magnified View.

If any points between a positive zero crossing and a negative zero crossing exceed HREF, then a signal has been found. Figure 4.3.2 Full Size View displays such a case.

REF is defined as:

$$REF = NOISEFLOOR + 10 \tag{4.1}$$

Equation 4.1 is stated in terms of sample quantization level. Signal samples may range from 0 to 255. Equation 4.1 was developed through trial and error experimentation. If REF is in the noisefloor, program execution is slowed by an excessive number of REF crossings. If REF is too high, weak signals will be missed. Equation 4.1 sets REF high enough to avoid false triggers caused by the noisefloor. REF is also high enough to discern adjacent signals with skirts that do not return to the noisefloor. (See Figure 4.3.3). NOISEFLOOR is the noisefloor level. A histogram is used to determine NOISEFLOOR.

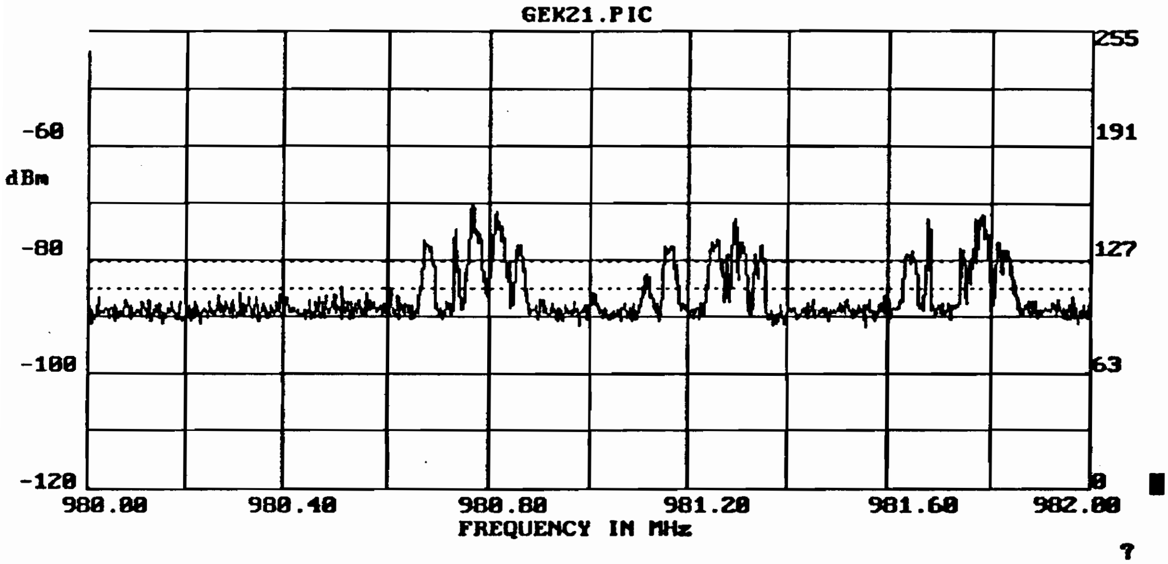


Figure 4.3.3 - Poor Signal Definition

HREF is defined as:

$$HREF = REF + 8 \tag{4.2}$$

Like Equation 4.1, Equation 4.2 is stated in terms of sample quantization level and was defined through trial and error experimentation. Equation 4.2 sets HREF high enough to miss most noise spikes and low enough to catch most weak
signals.

Bandwidth, which is defined in Figure 4.3.2 Full Size View, is the first feature that the decision tree uses. If a signal's bandwidth is less than 70 kHz, it is passed to the next stage of feature extraction.

Transience and signal grouping are used to sort narrowband signals into specific catagories. Some narrrowband signals, such as VSAT inbound signals, are transient by nature. They will appear during one sweep and disappear during the following sweep. Transience for individual signals is expressed as a mean difference. Figure 4.3.5 shows how transience is calculated for an individual signal. This operation is applied to each narrowband signal found in screen one.

A second transience feature is calculated for a group. A group is defined as two or more narrowband signals that are spaced at intervals of 80 kHz or less.

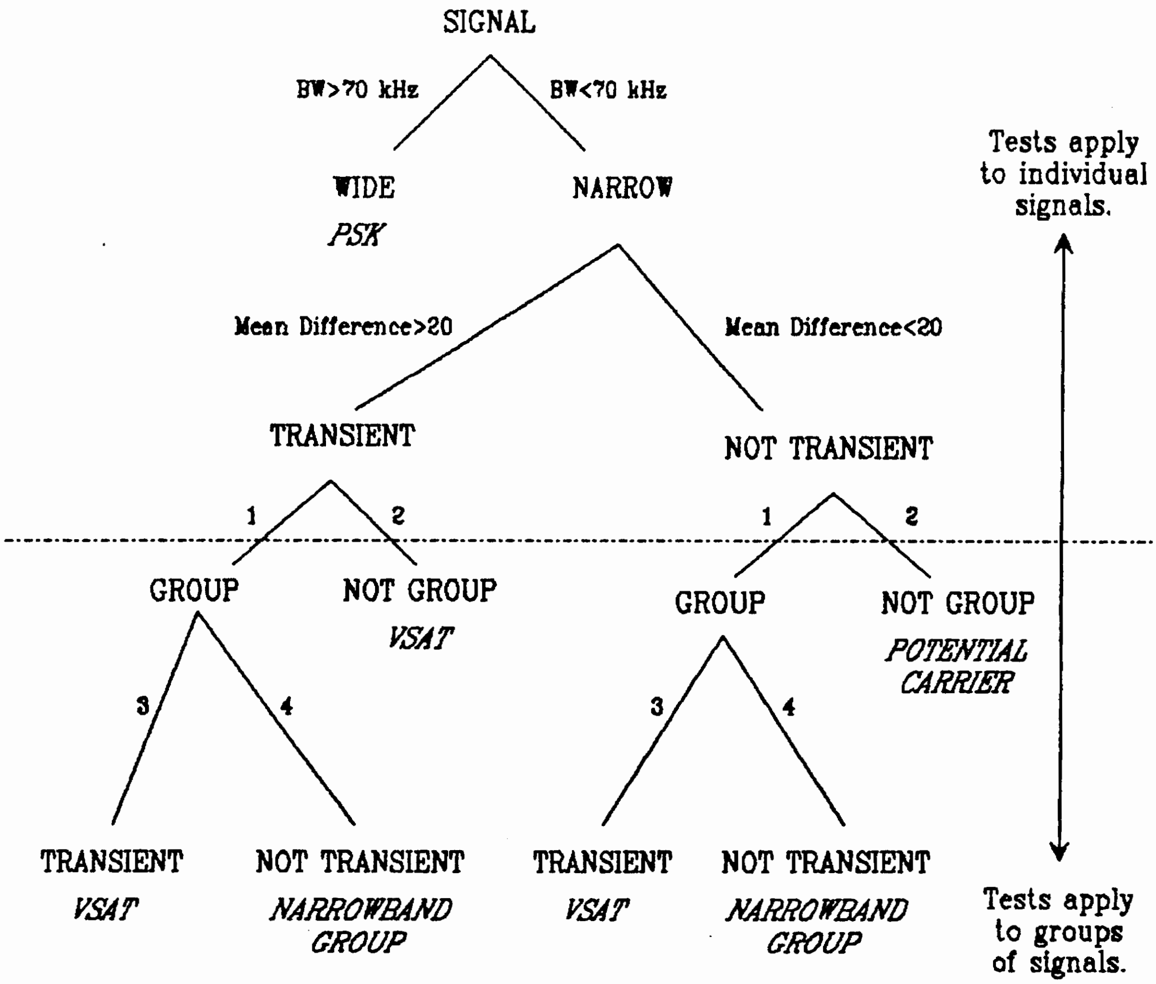
The mean differences of the members of a group are averaged to create the transience feature called the group average.

The feature extractor is done. The following features are available to the analyzer: bandwidth, grouping, mean difference, and group average.

4.3.2 - Analyzer

The analyzer uses a decision tree (Figure 4.3.4) to process features into signal labels. The decision tree starts with the signal in question. A signal is considered wideband if its bandwidth is greater than 70 kHz; otherwise it is considered narrowband. Observation indicated that spectra with a zero crossing bandwidth greater than 70 kHz are usually phase shift keyed (PSK) spectra. Spectra with a zero crossing bandwidth less than 70 kHz usually belong to several different narrowband catagories. The succeeding questions in the decision tree are devoted to assigning narrowband spectra to an appropriate catagory.

As a result of observation, it appeared that narrowband signals could be placed in three general catagories. Transient spectra were associated with VSAT (Very Small Aperture Terminal) systems. Some spectra consisted of regularly spaced groups of narrowband



1 – Adjacent signals are within 80 kHz.

2 – Adjacent signals are not within 80 kHz.

3 – Group average of mean differences>20.

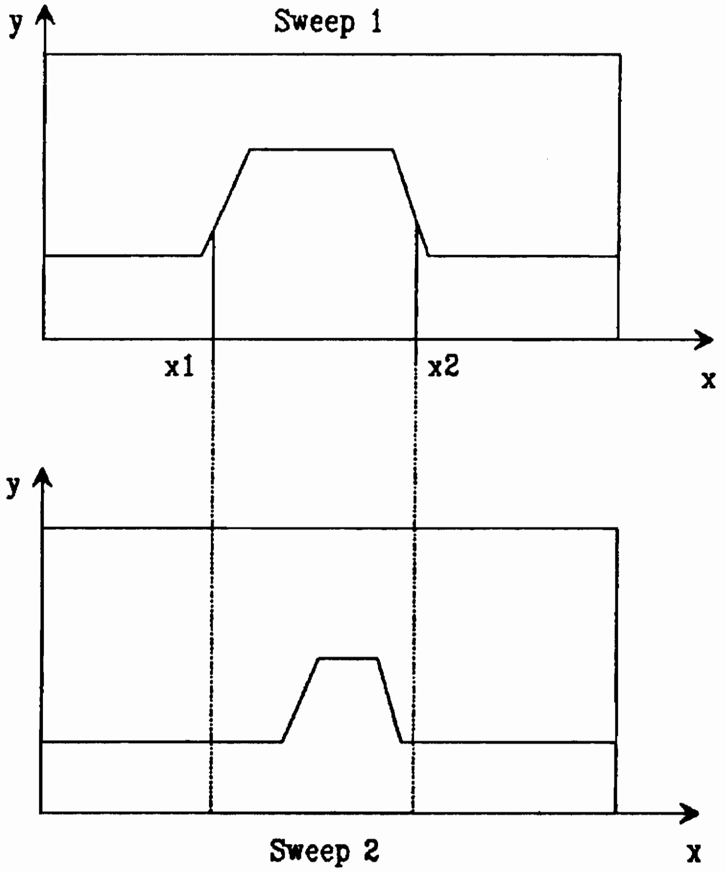
4 – Group average of mean differences<20.

Figure 4.3.4 – Decision Tree

signals, which suggested possible association with a FDMA system. Other constant narrowband signals appeared to be unmodulated carriers.

Several tests using features described in Section 4.3.1 are employed to separate the narrowband signals into these three catagories. The first test uses the mean difference which is shown in Figure 4.3.5. If the mean difference is greater than 20, the narrowband signal is considered transient; otherwise, the narrowband signal is considered not transient. Referring to Figure 4.3.4, the decision process has reached the TRANSIENT and NOT TRANSIENT labels above the dashed line.

Next, grouping is considered. A lonely transient signal is assigned the VSAT label. A lonely non-transient signal is assigned the Potential Carrier label. Since a random assortment of VSAT signals may satisfy the grouping requirement, grouping alone cannot be used to determine Narrowband Groups; the group average is used. If the group average is greater than 20, then each group member is given the VSAT label; otherwise, each group member receives the Narrowband Group label. The bottom of the decision tree has been reached so the recognition process stops. At this point, all detected signals have labels. An asterisk is appended to any label that is close to the decision boundary.



Note: This figure depicts two sweeps from one screen.

$$\text{Mean} = \left| \frac{\sum_{i=x1}^{x2} \left(ysweep1(i) - ysweep2(i) \right)}{x2 - x1} \right|$$

Figure 4.3.5 – Mean Difference

4.4 - Summary of Labels

Label	Conditions
PSK	Zero crossing bandwidth greater than 70 kHz.
VSAT	Mean difference greater than 20 **or** Group average greater than 20. Zero crossing bandwidth less than 70 kHz.
NBND GRP	Group average less than 20. Zero crossing bandwidth less than 70 kHz.
POTENTIAL CARRIER	Mean difference less than 20. Not part of a group. Zero crossing bandwidth less than 70 kHz.

An * appended to a label indicates that the test conditions were narrowly passed and therefore the label may be erroneous.

Appendix 4A - Operator's Manual for Recognition System Software

The recognition system consists of two programs: OBSERVE.BAS and RECGNIZE.BAS. OBSERVE.BAS is used to capture spectrum analyzer pictures. OBSERVE.BAS is designed for consecutive screen captures, two sweeps per screen. When user action is required, the program provides the appropriate prompt. The user is also given the opportunity to halt observation between captures. The user is guaranteed to have a flawless observation session if the prompts are followed.

RECGNIZE.BAS is used to process the resulting picture files into observation reports. Observations and observation reports may be viewed using RECGNIZE.BAS.

How to Use OBSERVE.BAS

OBSERVE.BAS starts with the screen shown in Figure 4A.1. Typing the number of a particular entry and ENTER will provide access to that setting. Entry 2, the resolution bandwidth, and entry 3, the frequency span per division, should not be adjusted if the resulting picture files are to be used with RECGNIZE.BAS. Be sure that the spectrum analyzer vertical setting match entries 5 and 6.

```
                    OBSERVATION PROGRAM
    SETUP SCREEN - TYPE THE NUMBER OF THE SELECTION FOR ACCESS.

1.  START FREQUENCY       950 MHz
2.  RESOLUTION BW         30 kHz
3.  SPAN/DIV              200 kHz
4.  FILE NAME ROOT       TEST
5.  2710 REFERENCE LEVEL -40 dBm
6.  dB PER DIVISION       10 dB

Commence picture Acquisition - A.
DIR *.PIC                    - F.
Quit                         - Q.

Take care not to write over your data!
?
```

Figure 4A.1 - OBSERVE.BAS Menu

To capture a series of screens, first select entry 1 and specify the start frequency of your observations.

Then, choose entry 4 to specify the root file name. The picture files produced by OBSERVE.BAS are named *.PIC. Up to the first four letters in * are user selectable via entry 4. The program will prohibit longer root names. As the program operates, it will append the observation number to the root name. For example, if the root name is NICE and the second screen has been captured, the program will store that screen under NICE2.PIC.

Once an appropriate root file name has been chosen, type A and then ENTER to commence the capture operation. The screen shown in Figure 4A.2 will appear. Heed all failsafe prompts. Before hitting RETURN, ascertain that the spectrum analyzer is set correctly and that the A/D/RS-232 board is connected and plugged in.

The program will now run on its own. After every two sweeps, a failsafe prompt will appear reminding you to advance the spectrum analyzer's start frequency. The program will also give you the opportunity to stop between screens.

```
Make sure that the spectrum analyzer is set to:
200 kHz SPAN/DIV
 30 kHz RESBW
 10 dB/vertical division
Other settings are not compatible with RECGNIZE.BAS.
Hit any key to continue?
```

Figure 4A.2 - OBSERVE.BAS Failsafe Screen

Once you complete an observation run, you may proceed to RECGNIZE.BAS for processing.

How to Use RECGNIZE.BAS

Figure 4A.3 shows the command screen in RECGNIZE.BAS. To begin the processing of *.PIC files, you must provide the *.PIC root name (entry 1). You must also supply a root name suitable for storing the observation reports (entry 2). The observation reports are stored on a screen by screen basis in *.DAT files. The number of a *.DAT file will correspond to the *.PIC from which the raw data was obtained.

Entries 3, 4, and 5 are vestiges from earlier program versions that required operator intervention. Entries 3 and 4 will control the placement of dashed lines that correspond to REF and HREF on graphs produced by G1 or G2.

To store an entire transponder observation report in one file, provide a suitable filename at entry 7. No utility exists to read this file, but it may be dumped to a printer for your use.

```
                    RECOGNITION PROGRAM
     SETUP SCREEN - TYPE THE NUMBER OF THE SELECTION FOR ACCESS.

1.  FILE NAME ROOT (INPUT)  TEST
2.  FILE NAME ROOT (OUTPUT) OUT
3.  ZERO CROSS LEVEL         111.5
4.  SPURIOUS LEVEL           126.5
5.  VSAT/FM LEVEL            20
6.  FILE NAME (PLOT/DIS)
7.  SESSION FILE NAME
8.  FORWARD PLOT REVIEW

Analyze data    - R.
Display results - D.
Graph screen 1  - G1.
Graph screen 2  - G2.
DIR *.PIC       - P.
DIR *.DAT       - T.
To quit, type Q.

This program isn't idiot-proof.  Don't write over your data!
?
```

Figure 4A.3 - RECGNIZE.BAS Menu

To commence processing, type R followed by ENTER. Answer the prompt that asks for the number of files to be processed. Hit ENTER, sit back, and let the program operate. Occasionally, screen messages will appear that indicate that *.DAT files are being written to the hard drive. When the processing is complete, respond to the ending prompt with an ENTER and you will return to the main menu.

To view a *.PIC or a *.DAT file, provide entry 6 with the root name and the proper number. For example, the second observation using the root name NICE is NICE2.PIC and the second data file would be NICE2.DAT. NICE2 would satisfy entry 6.

G1 will display the first sweep. G2 will display the second sweep. D will display the observation report in a neat format.

Chapter 5 - Hardware

5.0 - Chapter Summary

This chapter presents the recognition system hardware. As shown in Figure 5.1.1, the recognition system hardware consists of a TVRO system, spectrum analyzer, custom video sampler board, and an AT-compatible computer. The TVRO system receives Ku-band satellite signals. The spectrum analyzer displays the satellite signal spectra. The custom video sampler board provides the computer with a digitized version of the analog video output of the spectrum analyzer. The computer produces an observation report and record based on the data from the video sampler board. The hardware is described in Section 5.1.

Section 5.2 describes the design and operation of the custom video sampler. As shown in Figure 5.2.1, this board converts the analog video output of the spectrum analyzer into a digital data stream that is sent to the computer. Due to its function, the video sampler is called an A/D/RS-232 board. Section 5.2.1 describes the board operation and includes Figure 5.2.1, a board block diagram. Section 5.2.2 describes the board design and includes Figure 5.2.2, a board schematic diagram. The use of a GPIB controlled spectrum analyzer would obviate the need for the custom video sampler board.

5.1 - Description of the Hardware

The Satellite Communications Lab at Virginia Tech has a Scientific-Atlanta Ku band TVRO (TV Receive Only) system. The roof part of the TVRO system includes a 2.8 meter dish antenna and feed system. The lab part of the TVRO system includes a receiver that acts as the TVRO system's command center.

The received signal starts its path to the recognition system via the 2.8 meter diameter dish antenna atop Whittemore Hall. The antenna focuses the received signal on a feed system equipped with an OMT (orthomode transducer) and two LNBs. One LNB (a low noise amplifier and downconverter) is assigned to vertically polarized signals; the other to horizontally polarized signals. The OMT separates the received vertically and horizontally polarized signals into the LNBs. Each 10.75 GHz LNB local oscillator shifts the received 11.7-12.2 GHz Ku band signal down to 950-1450 MHz. Coax cable attenuates signals in this frequency range much less than signals in the Ku band frequency range.

Each signal polarization travels via individual coax cables from the LNBs to a Scientific-Atlanta Homesat 900 TVRO receiver in the Satcom Lab. The receiver is the receive system command center. It provides DC power to the LNBs, allows the user to select the receive

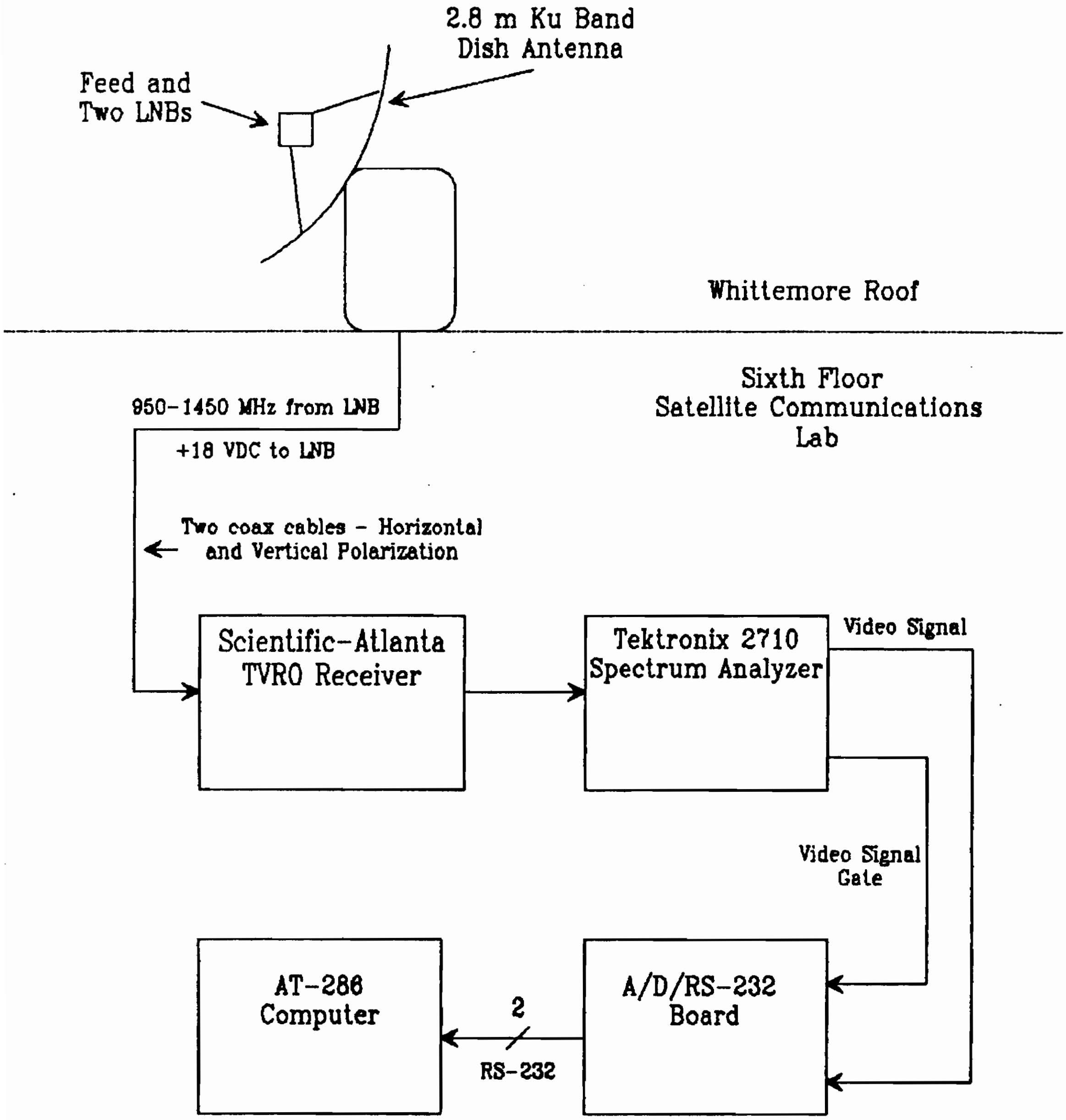


Figure 5.1.1 - Recognition System Block Diagram

polarization, and allows the user to control the actuator which steers the antenna across the geostationary arc.

The receiver has several rear panel outputs. For a home system, the receiver's primary job is the demodulation of FM video, more commonly known as satellite TV. The recognition system, however, uses the receiver's 950-1450 MHz RF OUT port to feed unprocessed satellite signal spectra to a Tektronix 2710 Spectrum Analyzer.

The spectrum analyzer is not equipped with the optional GPIB (General Purpose Instrument Bus) controller. It does have a female DB-9 connector (J103) on the rear panel that provides access to a gated analog video signal (pin 3), a sweep ramp (pin 7) which represents the sweep's progress, and the video signal gate (pin 6). The gated video signal represents the complement of the screen display.

The gated video signal only presents the contents of display memory register D. Also, the display mode has to be set to MIN/MAX, not PEAK. Register D holds the contents of the current sweep which was usually displayed on the front panel. Memory registers A-C are used for special spectrum analyzer functions such as MAX HOLD. The contents of these registers are not available outside of the spectrum analyzer. A full explanation of the spectrum analyzer's features and settings may be found in the Tektronix 2710 Spectrum Analyzer Owner's Manual [17].

To convert the gated analog video signal into a digital representation appropriate for computer use, an A/D (Analog-to-Digital) board was needed. Since the RS-232 port was the only completely bi-directional PC port, it was a logical data port choice. The board's function then became an A/D/RS-232. Figure 5.2.1 is a block diagram of the board.

The A/D/RS-232 board converts the analog video output of the spectrum analyzer into a digital data stream. The RS-232 standard data stream is sent to the AT-286's serial port. From there, the data is processed by the software, which is described in Chapter 4.

5.2 - A/D/RS-232 Board

5.2.1 - A/D/RS-232 Board Overview

The A/D/RS-232 board, as shown in Figure 5.2.1, converts the spectrum analyzer's analog video signal output into a serial data stream of digitized video samples. The data is then sent to the computer for use in the recognition program. The A/D/RS-232 board also converts the spectrum analyzer's video gate signal from TTL level to RS-232 level and then sends it to the computer. The computer program uses the video signal gate as a start/stop sampling trigger.

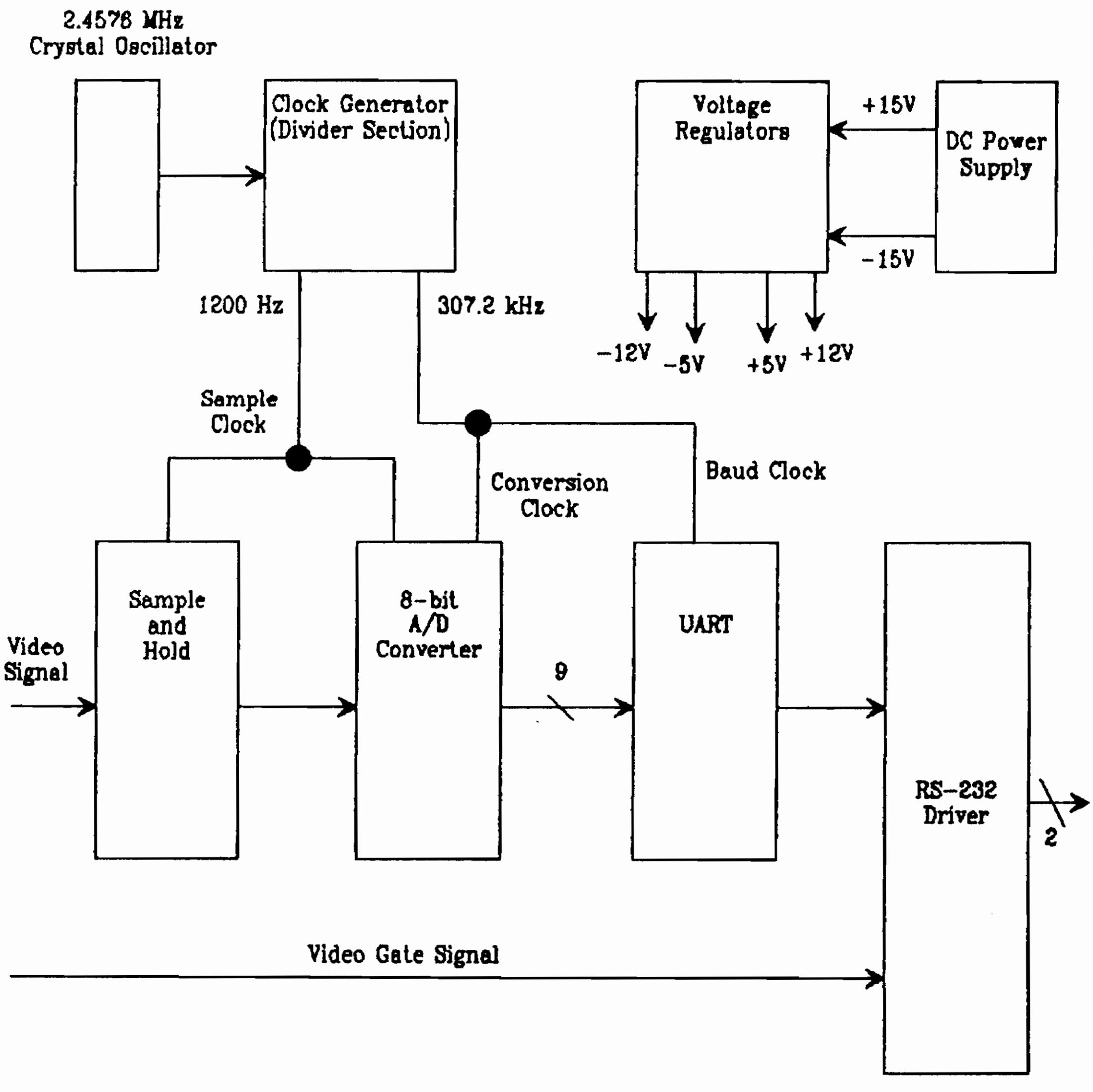


Figure 5.2.1 – A/D/RS-232 Block Diagram

The A/D/RS-232 board accepts the spectrum analyzer's analog video output and video gate signal. The video signal is sent to a sample-and-hold. An A/D converter accepts the output of the sample-and-hold and produces a parallel 8-bit data word which is sent to a UART (Universal Asynchronous Receiver Transmitter). The UART arranges the A/D converter's parallel output into a RS-232 format serial data stream. A RS-232 driver translates the UART output and the video signal gate from TTL to RS-232 voltage levels. The RS-232 driver's output is sent to the computer's serial port.

Two signals from the spectrum analyzer enter the A/D/RS-232 board: gated video signal from pin 3 and video signal gate from pin 6. The gated video signal, whose range is 0-1.6V, is sent to a sample-and-hold. A 1200 Hz clock controls the sample-and-hold and gates the A/D conversion process.

During the hold period, an A/D converter converts the input DC level into a parallel 8-bit word. A 2.5V voltage reference and an op-amp provide the A/D reference voltage. An all 1's output (255) corresponds to a 1.6V DC input.

Upon completion of the conversion process, the A/D converter provides the UART (Universal Asynchronous Receiver Transmitter) with an interrupt signal and a parallel 8-bit data word. The interrupt signal opens the UART's input buffers to accept the parallel data. The

UART produces a TTL level 19.2 kb/s RS-232 serial data stream with one start bit, two stop bits, and no parity bit.

A RS-232 driver translates the UART output and the video gate signal from TTL to RS-232 voltage levels. The output of the RS-232 driver, which is the output of the board, is sent to the AT-286 computer's RS-232 port.

Clock generation and voltage regulation are ancillary board sections. The clock system is driven by a 2.4576 MHz crystal oscillator. Several dividers provide the 1200 Hz sample-and-hold clock and the 307.2 kHz baud rate clock.

A dual ended power supply provides +15VDC and -15VDC which are regulated to +5V, -5V, +12V, and -12V. Bypass capacitors are used on the regulator inputs and outputs to control power supply noise. A .01 uF capacitor on the +5V regulator input is necessary to obtain glitch-free A/D operation. Single-sided copper clad perfboard provides a good circuit ground.

5.2.2 - A/D/RS-232 Board Design

Before board design commenced, performance requirements were specified. A minimum of 1024 points per screen was chosen based on the performance of a experimental setup that used a GPIB controlled DSO

(Digital Storage Oscilloscope) to capture a spectrum analyzer's video output. The DSO used 1024 points per screen, a resolution that provided high quality pictures.

Since the gated video signal swung 0V to 1.6V, 8-bit quantization provided 6.23mV resolution. This resolution corresponds to 32 points per vertical division. The National Semiconductor ADC0804, an inexpensive 8-bit A/D converter, was chosen. As suggested in the applications notes which accompanied the A/D converter data sheet, the LF 398 sample-and-hold IC was chosen.

The board's design required attention to many interdependent timings, starting with the output baud rate. To calculate the board's output baud rate, the spectrum analyzer's sweep time was needed. Initially, the standard spectrum analyzer settings were 100 kHz per horizontal division and 30 kHz resolution bandwidth. These settings resulted in a sweep time, as set by the spectrum analyzer, of 0.5s per screen. 8-bit data words that included one start bit and two stop bits provided 11 bits per conversion. At 19.2 kb/s, the fastest standard RS-232 baud rate, a maximum of 1745 conversions/s could be fed to the computer, a rate insufficient for the 1024 points per screen per 0.5s specification. Manually setting the spectrum analyzer's sweep rate to 1s per screen solved this problem. As software development continued, the standard spectrum analyzer setting was changed to 200 kHz per horizontal division and 30 kHz resolution bandwidth. The spectrum analyzer then automatically set the sweep rate to 2s per screen.

Having chosen the 19.2 kb/s data rate, several clock rates had to be fixed. The Universal Asynchronous Receiver Transmitter (UART) was responsible for converting the parallel output of the A/D converter into a RS-232 format serial data stream. It required 307.2 kHz (16x baud rate) to operate at 19.2 kb/s. A 307.2 kHz clock was obtained by dividing 2.4576 MHz, a common crystal oscillator block, by 8. The master clock oscillator, 2.4576 MHz was now fixed.

The sample-and-hold sample clock fixes the conversion rate. The conversion rate has to fit between 1024 conversions/s, a bound set by the desired number of points per screen, and 1745 conversions/s, a bound imposed by the baud rate. Dividing the master clock by 2048 provided a 1200 Hz sample clock, which also was used to start the A/D conversion process.

The A/D converter required a conversion clock that would accomodate between 66 and 73 clock cycles per conversion. Also, one conversion had to occur during one half of a sample-and-hold cycle. These requirements resulted in a minimum clock rate of 175.2 kHz. The nearest available clock rate was 307.2 kHz (2.4576 MHz/8).

With the clock rates set, most of the board design was complete. Several counter chips divided the 2.4576 MHz crystal clock down to other clocks. Careful attention was paid to the voltage regulation. The +5V regulator, in particular, required a .01 uF capacitor to suppress noise which caused A/D converter glitches.

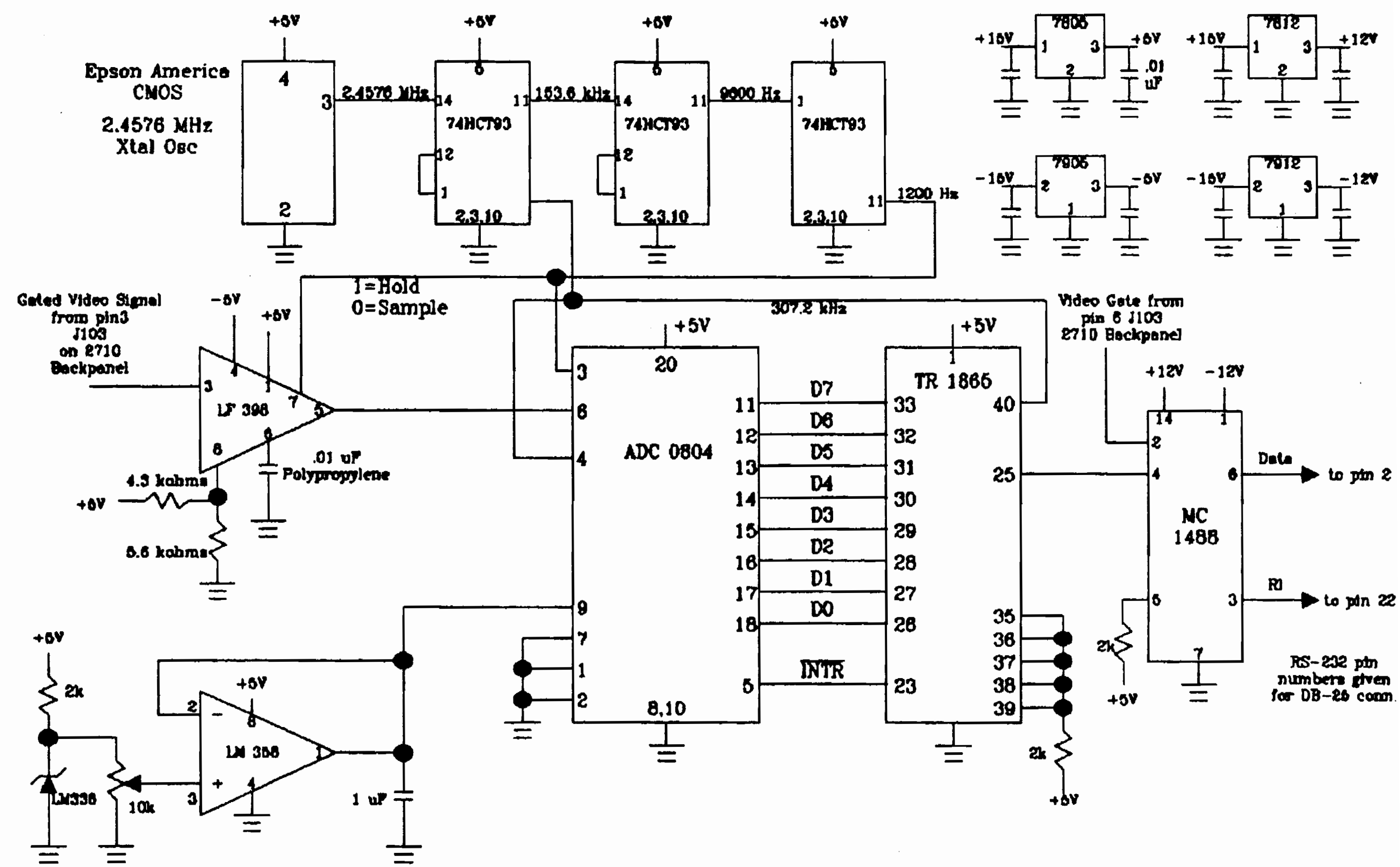


Figure 5.2.2 - Schematic Diagram of A/D/RS-232 Board

Chapter 6 - Results

6.0 - Chapter Summary

Chapters 4 and 5 describe the software and hardware sections of the recognition system. This chapter presents the results of using the recognition system for observing, cataloging, and labeling spectra found on the data transponders. Examples of program output for several Ku-band satellite transponders are presented.

6.1 - Individual Screen Examples

All of the figures and tables in this chapter were produced using RECGNIZE.BAS. The figures display captured spectrum analyzer screens. These screens conform to a common format. The x-axis displays the LNB output frequency in MHz. The y-axis displays power amplitude in dBm on the left and in quantization level on the right. The lower dashed line is REF, the zero crossing level. The upper dashed line is HREF, the false trigger level. The *.PIC filename is listed at the top of the graph. In all cases, the spectrum analyzer settings were 200 kHz per horizontal division, 10 dB per vertical division, and 30 kHz resolution bandwidth. Each picture file includes two consecutive sweeps of a particular screen.

Signal statistics and signal labels are in tables that were produced with RECGNIZE.BAS. The possible signal catagories are: PSK, VSAT, Narrowband Group, and Potential Carrier. Graph and table names are:

Signal Type	Graph	Table
PSK	Fig 6.1.1	Table 6.1.1
VSAT	Fig 6.1.2a,b	Table 6.1.2
Narrowband Group	Fig 6.1.3	Table 6.1.3
Potential Carrier	Fig 6.1.4	Table 6.1.4

A graph/table source is indicated by the filename prefix:

Prefix	Satellite
GEK2	GE Satcom K2
GTE2	GTE Spacenet 2

The GEK2 files are from transponder 1 (vertical polarization). The GTE2 files are from transponder 1 (horizontal polarization).

Figure 6.1.1 contains several wideband PSK signals. In the context of the recognizer, the label 'PSK' indicates a wideband signal since nearly all wideband signals are PSK signals. Many of the other graphs presented also contain wideband PSK signals. This is the easiest signal to detect because it is constant.

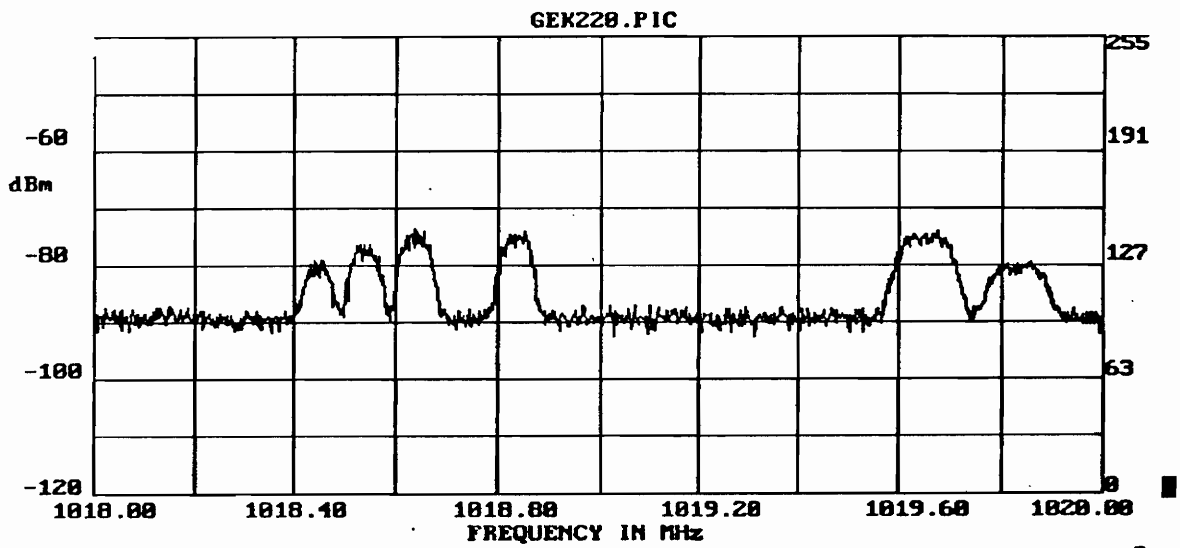


Figure 6.1.1 - Captured PSK Signals

Table 6.1.1 - Observation Report for Fig. 6.1.1

FILENAME = GEK220.DAT from GEK220.PIC
START FREQ (MHz) 1018.00 SPAN/DIV (kHz) 200.00 RES BW (kHz) 30.00
REFERENCE LEVEL = 107.5

SIG NUM	CNTR FREQ(MHz)	BW (kHz)	C/N (dB)	SIGNAL TYPE
1	1018.44	64.52	8.3	POTENTIAL CARRIER
2	1018.54	82.11	10.6	PSK
3	1018.64	91.89	12.5	PSK
4	1018.83	86.02	12.6	PSK
5	1019.65	158.36	12.5	PSK
6	1019.83	130.99	8.3	PSK

Press any key to return to menu?

Figures 6.1.2a and 6.1.2b display screen one and screen two of GEK24.PIC. These figures contain typical VSAT activity; both screens are shown to indicate the transient nature of VSAT signals. The PSK signal to the left of the VSAT activity may be the outbound link. VSAT activity is usually associated with a wideband PSK signal, which is probably the user-to-hub (outbound) link. Refer to Chapter 2 for a more detailed discussion of VSAT systems.

An interesting aspect of this particular group is the actual bandwidth of the transmitted signal. If the spectrum analyzer is set to MAX HOLD mode, and thirty sweeps are performed, it becomes clear that the spiky signals are a result of slowly sampling a transient wideband signal.

Narrowband Group signals can be seen in Figure 6.1.3. GE Satcom K2 carries several narrowband groups. These signals may be part of a FDMA-SCPC system. The unavailability of precise frequency information hinders the use of an accurate label.

Figure 6.1.4 displays a Potential Carrier. This signal is constant from one screen to the next. The 30 kHz resolution bandwidth keeps the signal from assuming the spike shape of a carrier. From observation, it is known that this signal contains one frequency component. If the resolution bandwidth were halved for the

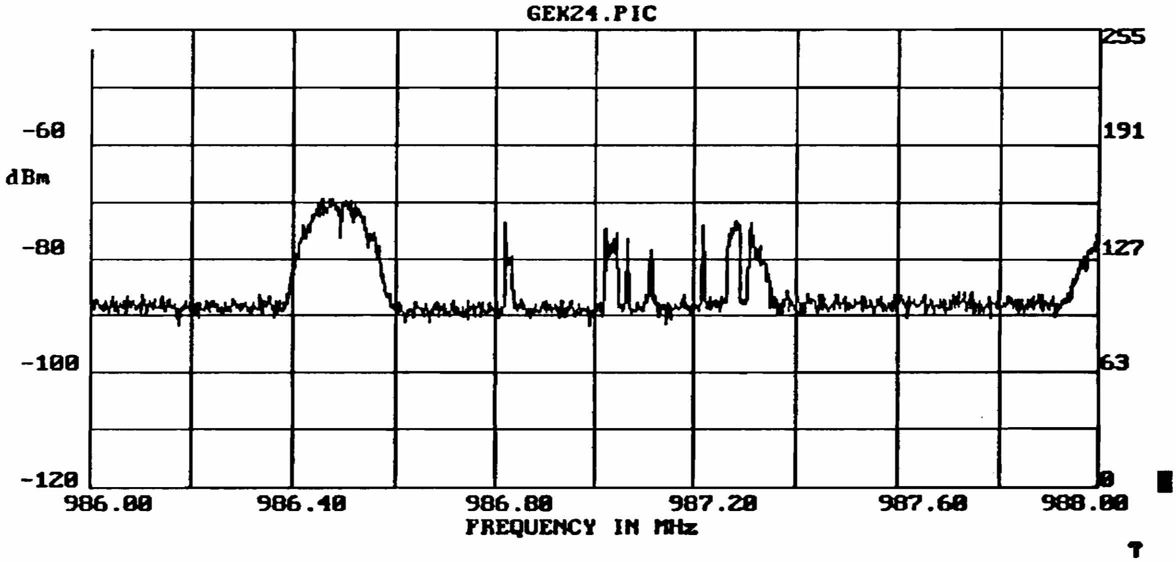


Figure 6.1.2a - Captured VSAT Signals (Sweep 1)

Table 6.1.2 - Observation Report for Figure 6.1.2a

FILENAME = GEK24.DAT from GEK24.PIC

START FREQ (MHz) 986.00 SPAN/DIV (kHz) 200.00 RES BW (kHz) 30.00

REFERENCE LEVEL = 110.5

SIG NUM	CNTR FREQ(MHz)	BW (kHz)	C/N (dB)	SIGNAL TYPE
1	986.48	191.59	15.6	PSK
2	986.83	17.60	8.4	VSAT
3	987.03	29.33	10.9	VSAT
4	987.07	3.91	10.6	VSAT
5	987.11	11.73	7.3	VSAT
6	987.22	5.87	8.6	VSAT
7	987.28	27.37	13.5	VSAT
8	987.33	43.01	9.9	VSAT
9	987.97	56.70	8.9	POTENTIAL CARRIER

Press any key to return to menu?

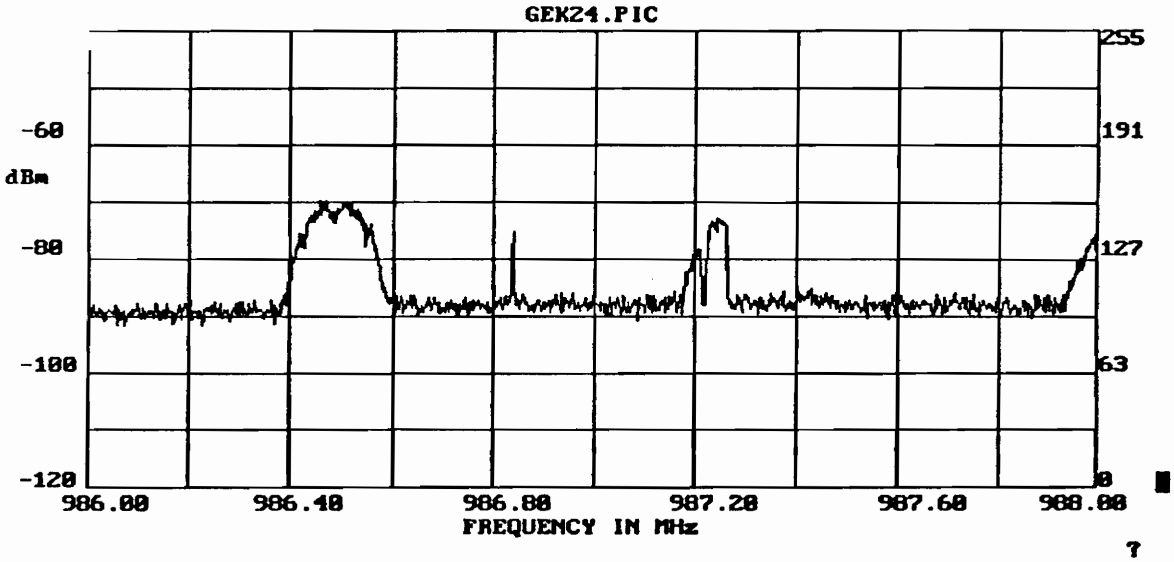


Figure 6.1.2b - Captured VSAT Signals (Sweep 2)

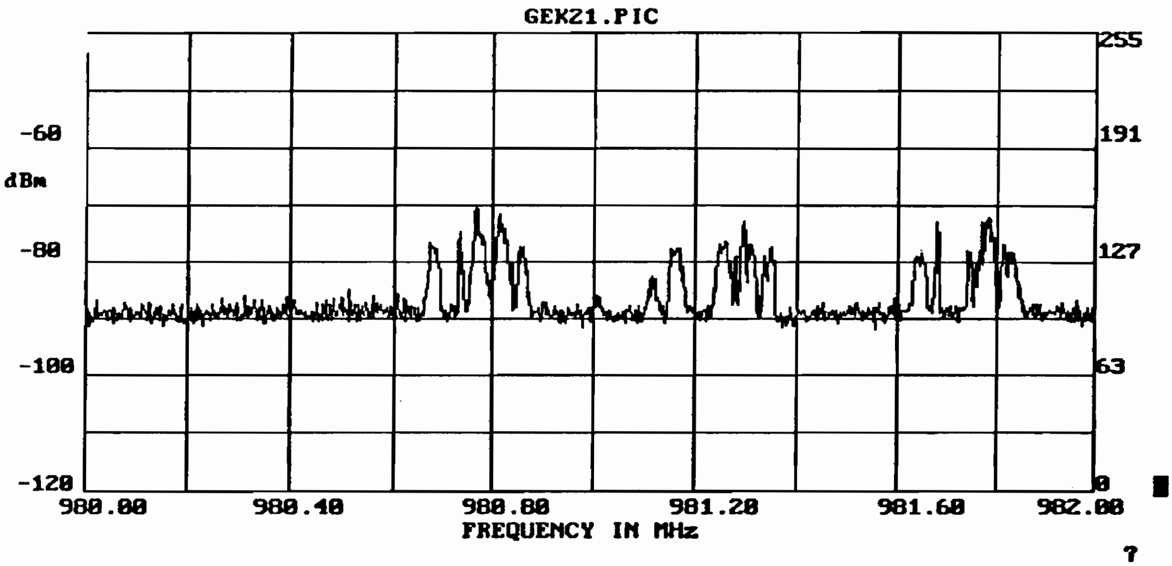


Figure 6.1.3 - Captured Narrowband Group Signals

Table 6.1.3 - Observation Report for Figure 6.1.3

FILENAME = GEK21.DAT from GEK21.PIC
START FREQ (MHz) 980.00 SPAN/DIV (kHz) 200.00 RES BW (kHz) 30.00
REFERENCE LEVEL = 109.5

SIG NUM	CNTR FREQ(MHz)	BW (kHz)	C/N (dB)	SIGNAL TYPE
1	980.68	33.24	9.6	NBND GRP
2	980.74	13.69	10.9	NBND GRP
3	980.77	43.01	13.3	NBND GRP
4	980.82	44.97	12.9	NBND GRP
5	980.86	21.51	9.6	NBND GRP
6	981.12	13.69	5.3	NBND GRP
7	981.16	33.24	9.8	NBND GRP
8	981.25	41.06	9.6	NBND GRP*
9	981.28	5.87	9.4	NBND GRP*
10	981.30	37.15	11.7	NBND GRP*
11	981.35	27.37	9.0	NBND GRP*
12	981.65	29.33	8.9	NBND GRP*
13	981.68	15.64	10.8	NBND GRP*
14	981.74	13.69	8.1	NBND GRP*
15	981.78	44.97	13.2	NBND GRP*
16	981.83	37.15	9.6	NBND GRP*

Press any key to return to menu?

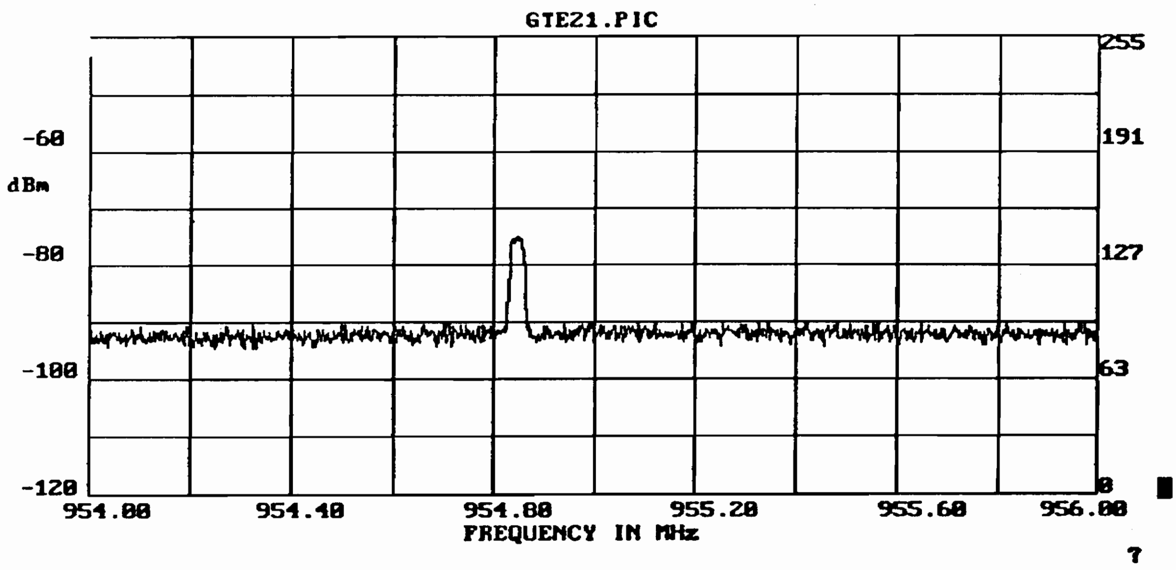


Figure 6.1.4 - Captured Potential Carrier

Table 6.1.4 - Observation Report for Figure 6.1.4

FILENAME = GTE21.DAT from GTE21.PIC
START FREQ (MHz) 954.00 SPAN/DIV (kHz) 200.00 RES BW (kHz) 30.00
REFERENCE LEVEL = 99.5

SIG NUM	CNTR FREQ(MHz)	BW (kHz)	C/N (dB)	SIGNAL TYPE
1	954.85	37.15	15.3	POTENTIAL CARRIER

Press any key to return to menu?

recognition system, the sweep time would be extended four-fold. In the interest of expedient observation, the resolution bandwidth was chosen to be 30 kHz and the frequency span per division was chosen to be 200 kHz.

6.2 - Problems - Observation and Identification

A single 56 MHz wide transponder requires approximately thirty *.DAT and *.PIC files. Most signals are properly identified; however, errors do occur occasionally. Some of the errors are due to problems in the decision tree; others are due to the observation system.

A wrong turn in the decision tree will result in an improper identification. The first error can occur in the bandwidth test. The first signal in Figure 6.1.1 is a PSK signal. However, its zero crossing bandwidth is under 70 kHz, as shown in Table 6.1.1; therefore, the program considers the signal to be narrowband. Since it isn't a transient signal, it receives the Potential Carrier label. Lowering the threshold for wide/narrow would give this signal the proper identification. Modifying the threshold, however, could result in false PSK identifications. Although the detection levels were set empirically, the Neymen-Pearson criterion provides a theoretical description of the tradeoff between false detection and missed signal probabilites. Out of an entire transponder, very few false PSK errors occur.

During observation, a signal may lie on the edge of two frames. RECGNIZE.BAS can handle the overlap; however, errors can occur due to observation error. A PSK signal overlaps from GEK24.PIC into GEK25.PIC (see Figures 6.1.2a and 6.2.1a). A piece of the signal appears on the far right side of GEK24.PIC; the whole signal appears on the far left side of GEK25.PIC. The program labels the signal piece in GEK24.PIC as a potential carrier (Table 6.1.2) because it is narrow and constant. The entire PSK signal exists in GEK25.PIC, and the program labels it properly (Table 6.2.1). This observation error may be due to LNB local oscillator drift. The LNB local oscillator is specified for plus or minus 2 MHz drift. Observation indicates that it does not drift that far and that the oscillator drifts slowly. Also, the spectrum analyzer may be unreliable at the screen edges. Test equipment typically does not perform within specification at the limit of any of its ranges.

The program will miss some VSAT activity. To simplify program operation, screen one is the signal source. Screen two is used only for comparison; therefore, signals in screen two may be missed. Screen one of GEK25.PIC (Figure 6.2.1a) shows no VSAT activity between the first two PSK signals. Screen two (Figure

6.2.1b), however, displays VSAT activity between the first two PSK signals. The observation report (Table 6.2.1) does not record this fact.

Due to the spiky nature of the noise, REF and HREF crossings can occur that will result in a false signal. Most commonly, this error occurs with PSK signals, such as the first PSK signal in GEK25.PIC (Figure 6.2.1a). Careful examination of the graph will reveal the requisite zero crossings that are interpreted by the program as a potential carrier (see Table 6.2.1).

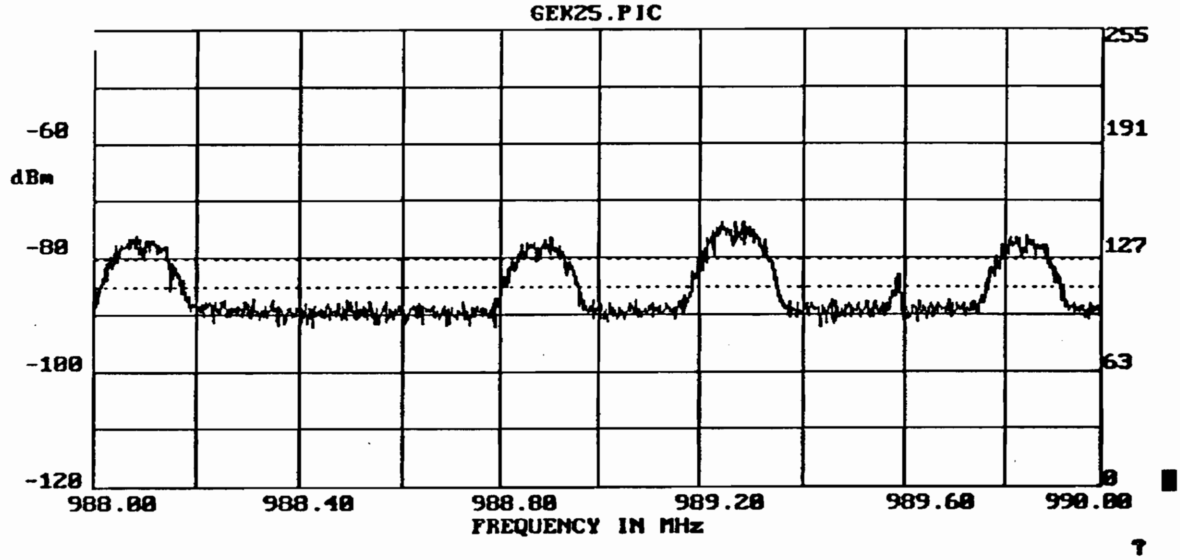


Figure 6.2.1a - Demonstration of Lost VSAT (Sweep 1)

Table 6.2.1 - Observation Report for Figure 6.2.1a

FILENAME = 6EK25.DAT from 6EK25.PIC
START FREQ (MHz) 988.00 SPAN/DIV (kHz) 200.00 RES BW (kHz) 30.00
REFERENCE LEVEL = 110.5

SIG NUM	CNTR FREQ(MHz)	BW (kHz)	C/N (dB)	SIGNAL TYPE
1	988.08	138.81	9.9	FSK
2	988.16	19.55	6.2	POTENTIAL CARRIER
3	988.88	162.27	8.8	FSK
4	989.27	168.13	11.5	FSK
5	989.84	154.45	9.5	FSK

Press any key to return to menu?

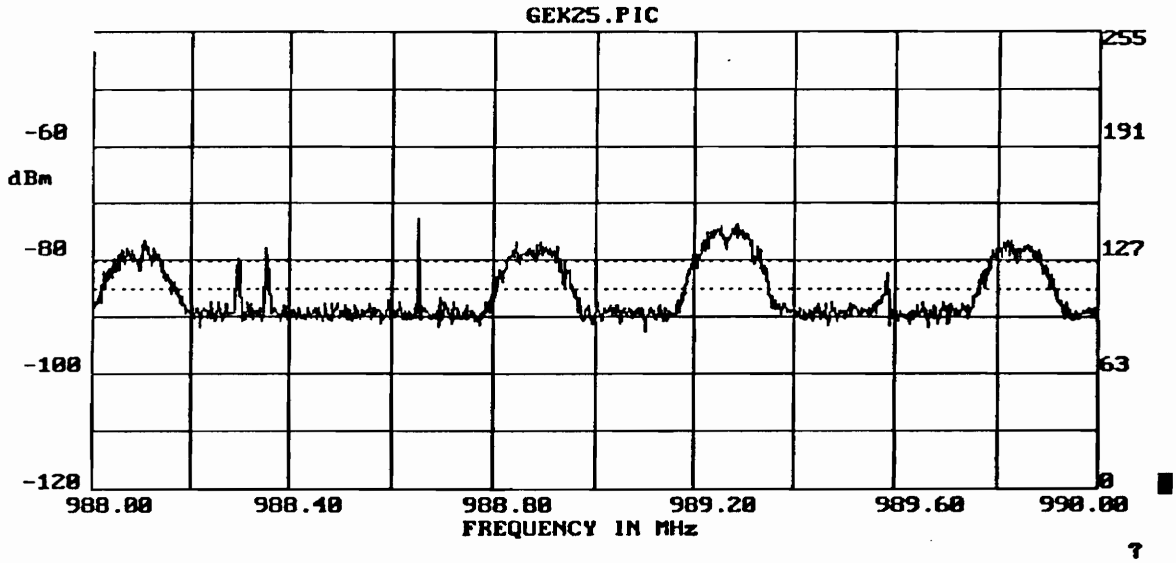


Figure 6.2.1b - Demonstration of Lost VSAT (Sweep 2)

Chapter 7 - Recommendation for Future Work

7.0 - Chapter Summary

The recognition system consists of two major parts: hardware and software. The performance of both parts could be improved. Chapter 7 details recommendations for future work.

7.1 - Software Improvements

Aside from satellite television listings [2], specific transponder frequency listings and corresponding traffic information could not be found. If this information could be obtained, more meaningful and specific labels could be incorporated into the recognition program.

The recognition program does not recognize SCPC-FM signals. Since only one SCPC-FM signal was found during a search of three Ku-band satellites, the problem of labeling SCPC-FM signals received a low priority.

7.2 - Hardware Improvements

One of the errors detailed in Chapter 6 resulted from the frequency drift of the LNB local oscillator. Several options could correct for the drift. A more stable downconverter could be used; however, this would probably be an expensive option. One of the features of this project, however, was the use of inexpensive satellite equipment.

If the the present equipment were used, the local oscillator frequency could be monitored. Spectra observations could be adjusted for the error in the LNB local oscillator.

The signal from a stable marker generator could be presented at the antenna. The generated marks would be in the observed band. The marks would be observed on the spectrum analyzer, and their position noted. The difference between the observed marks and the generated marks would indicate the error in the LNB local oscillator.

This project's goal was the creation of a system that would autonomously log and catalog satellite spectra. The recognition system's spectrum analyzer, however, requires a human operator. To realize the original intent of the project, a GPIB-controlled (General Purpose Instrument Bus) spectrum analyzer would be an important improvement.

The GPIB would give the computer complete control over the spectrum analyzer. The observation code would require modification to accomodate a GPIB-controlled spectrum analyzer.

A GPIB-controlled spectrum analyzer would also obviate a slight frequency shift that is introduced by the video sampler board. The video sampler board samples the spectrum analyzer's video output asynchronously. It was assumed that the spectrum analyzer swept at a constant rate. The spectrum analyzer, however, does not sweep at a constant rate which results in a slight frequency shift that is noticable if the captured screen is compared to the original screen. The first half of the screen is shifted slightly, to the left; the second half of the screen shows no shift. The frequency shift does not affect the identification of the signals; it manifests itself as a slightly incorrect center frequency.

Using the present system, the frequency shift could be corrected in two ways: software manipulation of data samples, or an improved sampler board. With software manipulation, a lookup table would provide a correction shift for each data point. This method would require a consistent shift pattern from screen to screen, but has the advantage of not requiring extra hardware.

The improved sampler board would use the spectrum analyzer's ramp sweep indicator. The position on the ramp corresponds to the sweep position. The sweep indicator could be sampled and used to adjust the sample rate. This modification would probably require a complete board re-design. The original board does not have an independent sample clock that is adjustable.

Chapter 8 - Conclusions

8.0 - Chapter Overview

The goal of this project was the construction of a system that would log and label Ku-band satellite signals found on satellite data transponders. The resulting system creates a permanent observation record and provides a nearly error-free observation report. In twenty minutes, a user can observe a 56 MHz wide transponder and produce an observation report that includes several signal statistics.

The recognition system can be divided into two main parts: hardware and software. This chapter is similarly divided. Conclusions regarding hardware are in Section 8.1. Conclusions regarding software are in Section 8.2.

8.1 - Observation System - Hardware

8.1.1 - Hardware Capabilites

The observation system hardware receives Ku-band satellite signals, displays signal spectra, and stores signal spectra in a disk file. The observation system hardware consists of a satellite TVRO (TV Receive Only) system, spectrum analyzer, custom video sampler board, and a personal computer. The TVRO system receives Ku-band satellite signals. The spectrum analyzer displays the satellite signal spectra. The custom video sampler board provides the computer with a digitized version of the analog video output of the spectrum analyzer. The computer produces an observation report and record based on the data from the video sampler board.

The assembled system worked as planned. A user could easily observe signal activity and save observed signals in a computer file that could be viewed or processed later. One of the requirements for the observation system stipulated the use of readily available equipment. This goal was achieved.

8.1.2 - Hardware Limitations

Some limitations of the observation system cause errors in the observation record. The spectrum analyzer and the LNB local oscillator drift cause slight frequency errors for signals that are close to the screen edge. These errors may manifest themselves as false signals. LNB local oscillator drift also introduces error into the center frequencies provided by the observation report. Chapter 7 describes several potential solutions for the LNB local oscillator drift.

The spectrum analyzer sweep is not constant in time.

Because the video output is sampled asynchronously, the resulting observation includes a frequency shift that is most noticible during the first half of the observation. Chapter 7 details three solutions to this problem.

To fully realize a completely autonomous observation system, a GPIB controlled spectrum analyzer should be used. Observations could be performed more quickly than the present system and without human intervention. Thirty percent of observation time is spent on setting the spectrum analyzer for the next observation and responding to failsafe computer prompts. A GPIB controlled spectrum analyzer would also obviate the video sampler board and, therefore, the frequency shift problem.

8.2 - Observation System - Software

8.2.1 - Software Capabilites

The software portion of the recognition system consists of two programs: OBSERVE.BAS and RECGNIZE.BAS. OBSERVE.BAS controls the observation phase of operation. It coordinates transponder observation sessions; it accepts and organizes digitized video samples into *.PIC files. These files form a permanent observation record that can be observed or processed at any time. RECGNIZE.BAS processes the observation record into an observation report. Each report includes observed signals and the following signal statistics: center frequency, bandwidth, C/N, and signal label. The possible signal labels are PSK, Narrowband Group, VSAT, and Potential Carrier. The observation reports are saved on disk as *.DAT files for later use.

8.2.2 - Recognition Program Performance

The observation reports are fairly accurate. Table 8.2.2.1 lists the label statistics for a single data transponder on GE Satcom K2. This transponder is chosen because it includes a diverse set of signals. The percent right column indicates the number of correct guesses over the total number of guesses for that particular label.

Table 8.2.2.1

Signal Name	Percent Right
PSK	95%
VSAT	70%
Narrowband Group	75%
Potential Carrier	>10%

There are few unmodulated carriers on a satellite transponder, therefore, only a few recognition errors will produce a low recognition score. Two recognition errors are primarily responsible for potential carrier mislabeling. If a PSK signal's bandwidth is too narrow to qualify as PSK, the decision tree will provide a potential carrier label. Also, noise spikes on PSK spectra skirts around REF tend to create potential carrier. These errors are detailed in Chapter 6, Section 2.

In twenty minutes, a user can capture an entire transponder and process observations into observation reports. It takes an additional thirty minutes to thoroughly compare the observation reports to the observations. The typical Ku-band satellite usually has five transponders devoted to data, so it would take 1 hour and 45 minutes to capture and process all of the data transponders on one satellite. It would take an additional 3 hours to thoroughly compare the observation reports with the observations.

8.2.3 - Recognition Program Advantages

The recognition program uses a decision tree to process selected signal features into a signal label. It does not require computationally intensive curve fit algorithms or the prior knowledge of signal statistics that other pattern recognition techniques need. The decision tree is very flexible. To add signals to the tree, new question nodes and branches may be added. If other pattern recognition techniques are found to be appropriate for certain types of signals, the tree can be used to narrow the range of signals fed to the alternate pattern recognition technique.

8.2.4 - Recognition Program Limitations

The recognition software accepts the observation record and produces signal labels and statistics. The program does have some problems. Due to limited signal information during programming, some of the labels are vague. For example, narrowband group describes the appearance of a specific group of signals but does not provide detailed information that a label like VSAT-FDMA would.

Some signals include noise-induced spikes that are sometimes misinterpreted as signals. A more sophisticated zero crossing system might filter these false signals. A numerically implemented low pass filter, such as a moving average filter, might be capable of removing noise while leaving the signals intact. Further investigation of the field of image processing may reveal several useful filter techniques.

Even with its faults, the output from the recognition program is fairly accurate. A user can compare an observation report with the corresponding observations using utilities included with the recognition program. Label errors or new signal types can be spotted easily and noted.

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Appendix A - OBSERVE.BAS

```
REM ERIC OLESEN  VIRGINIA TECH
REM OBSERVE.BAS    MAY 29,1992
REM THIS PROGRAM IS PART ONE OF A TWO PART PACKAGE.
REM THIS PROGRAM COORDINATES THE SIGNAL OBSERVATION SESSION AND
REM RECORDS THE SIGNALS OBSERVED.
REM
FILENUM=1
NOSE:
CLS
REM SETUP
GOSUB SETUP
NOSE1:
REM CAPTURE
GOSUB CAPTURE
REM DOITAGAIN
GOSUB DOITAGAIN
IF SETFLAG=1 GOTO NOSE
GOTO NOSE1
REM
REM ************************************************
SETUP:
REM ************************************************
REM
REM SETUP WILL DO JUST THAT.  USER WILL ENTER START FREQUENCY FOR
REM OBSERVATION SESSION, AND A FOUR LETTER NAME THAT WILL FORM THE
REM ROOT OF THE *.PIC FILE WHICH WILL STORE TWO FRAMES PER SCREEN.
REM THE STANDARD *.PIC FORMAT IS ASCII WITH A HEADER THAT INCLUDES
REM STFREQ,SPANDIV,RESBW,DBDIV,SCREENTOP.  SETUP WILL ALSO PROMPT
REM THE USER FOR THOSE VALUES; HOWEVER, THE RECOGNITION PROGRAM,
REM RECGNIZE.BAS IS DESIGNED FOR 200 kHz SPAN/DIV, 30 kHz RES BW,
REM AND 10 dB/DIV.
STFREQ=950:RESBW=30:SPANDIV=200:SCREENTOP=-40:DBDIV=10:ROOT$="TEST"
8010 CLS
PRINT"                              OBSERVATION PROGRAM"
PRINT"          SETUP SCREEN - TYPE THE NUMBER OF THE SELECTION FOR ACCESS."
PRINT
PRINT"1.  START FREQUENCY         ";STFREQ;"MHz"
PRINT"2.  RESOLUTION BW           ";RESBW;"kHz"
PRINT"3.  SPAN/DIV                ";SPANDIV;"kHz"
PRINT"4.  FILE NAME ROOT          ";ROOT$
PRINT"5.  2710 REFERENCE LEVEL    ";SCREENTOP;"dBm"
PRINT"6.  dB PER DIVISION         ";DBDIV;"dB"
LOCATE 11,1
PRINT"Commence picture Acquisition - A."
PRINT"DIR *.PIC                    - P."
PRINT"Quit                         - Q."
PRINT
PRINT"Take care not to write over your data!"
INPUT ZZ$
IF ZZ$="1" THEN
LOCATE 22
INPUT"Input new START FREQUENCY in MHz";STFREQ
```

```
GOTO 8010
END IF
IF ZZ$="2" THEN
LOCATE 22
INPUT"Input new RESOLUTION BW in kHz";RESBW
GOTO 8010
END IF
IF ZZ$="3" THEN
LOCATE 22
INPUT"Input new SPAN/DIV in kHz";SPANDIV
GOTO 8010
END IF
IF ZZ$="4" THEN
LOCATE 22
CHOOSEROOT:
INPUT"Input new FILE NAME ROOT";ROOT$
IF LEN(ROOT$)>4 THEN
PRINT"FILE NAME ROOT is too long.  Choose again."
        LOCATE 24
GOTO CHOOSEROOT
END IF
GOTO 8010
END IF
IF ZZ$="5" THEN
LOCATE 22
INPUT"Input new 2710 REFERENCE LEVEL (dBm)";SCREENTOP
GOTO 8010
END IF
IF ZZ$="6" THEN
LOCATE 22
INPUT"Input new dB PER DIVISION (dB)";DBDIV
        GOTO 8010
END IF
IF ZZ$="R" THEN RETURN
IF ZZ$="Q" THEN
CLS
INPUT"Are you sure that you want to quit? (Y)";ZZ$
IF ZZ$="Y" THEN
PRINT"Program concluded at user's request."
END
END IF
END IF
IF ZZ$="A" THEN
CLS
PICNAME$=ROOT$+"1.PIC"
PRINT"Make sure that the spectrum analyzer is set to:"
PRINT"200 kHz SPAN/DIV"
PRINT" 30 kHz RESBW"
PRINT" 10 dB/vertical division"
PRINT"Other settings are not compatible with RECGNIZE.BAS."
        INPUT"Hit any key to continue";ZZ$
GOTO CAPTURE
```

```
END IF
IF ZZ$="P" THEN
CLS
FILES"*.PIC"
LOCATE 21,1:PRINT"Hit return to continue."
INPUT Q$
END IF
GOTO 8010
RETURN
REM ************************************************
CAPTURE:
REM ************************************************
REM STFREQ,SPANDIV,RESBW,DBDIV,SCREENTOP AT THE TOP OF THE FILE
REM THIS IS A SUBROUTINE FOR READING A FRAME FROM THE SPECTRUM ANALYZER.
REM THE FRAME WILL CONSIST OF 1024 SAMPLES DURING A 1 SEC SWEEP OF THE SCREEN.
REM THIS PROGRAM CONFIGURES COM1 TO ACCEPT 19200 BAUD, 8BIT WORD, 2 STOP BITS
CLS
DIM DATARAW1(8000),DATARAW2(8000),FINALDATA(2050)
REM TURBO BASIC WON'T ALLOW OPEN COM TO SUPPORT>9600
REM SO I WILL DIRECTLY ADDRESS THE SERIAL PORT REGISTERS
REM IN ORDER TO SET UP 19200 BAUD, 8 DATA BITS, NO PARITY, AND 2 STOP BITS
REM SET THE BAUD RATE
REM FIRST, SET DLAB=1 TO GAIN ACCESS TO BAUD RATE DIVISOR
OUT &H3FB,&B10000000
REM NOW SET BAUD RATE, LSBYTE
OUT &H3F8,&H06
REM NOW SET BAUD RATE, MSBYTE
OUT &H3F9,&H00
REM NOW SET DATA BITS=8,PARITY NONE, STOP=2
REM SET DLAB=0
OUT &H3FB,&B00000000
REM SET PORT PARAMETERS
OUT &H3FB,&B00000111
REM DISABLE INTERRUPTS
OUT &H3F9,&B00000000
REM READY TO READ DATA FROM &H3F8. CAN CHECK FOR DATA READY USING &H3FD
REM BIT 0 WILL INDICATE A COMPLETE INCOMING CHARACTER WHEN IT IS 1.
REM
REM ORDER OF EVENTS
REM USER WILL INDICATE THAT HE WANTS A FRAME OF DATA.
REM PROGRAM WILL LOOK FOR THE SWEEP GATE TO GO TO 0.
REM DO NOT USE TRAILING EDGE OF RING INDICATOR!!!!
REM IT WILL INDICATE THE LOGIC HIGH TO LOW TRANSITION
REM OF RI AND HOLD THAT VALUE UNTIL IT IS READ. READING THAT VALUE FIRST
REM IS A TRULY BONEHEADED THING TO DO.
REM THEN, PROGRAM WILL LOOK FOR THE SWEEP GATE TO GO TO 1.
REM CHECK DATAREADY, IF IT IS, THEN READ DATA.
REM CHECK RI=0, IF NOT REPEAT READING OPERATION.
REM IF RI=0, THEN STOP READING DATA.
REM SIFT ENTRIES INTO 1024 ENTRIES.
REM STORE FILE ON DISK INCLUDING THE FILE HEADER SO THAT WHEN GRAPH
REM TIME COMES, THE GRAPH HAS ENOUGH INFORMATION TO PLACE THE DATA IN
```

```
REM APPROPRIATE CONTEXT.
REM &H3FE BIT#6 - RING INDICATOR
REM &H3FE BIT#2 - TRAILING EDGE RING INDICATOR
REM &H3FD BIT#0 - DATA READY
REM &H3F8 - DATA INPUT
REM
N1=0:N2=0
TRAIL:
TRAILING=INP(&H3FE)
TEST=TRAILING AND &B01000000
IF TEST=0 THEN GOTO TRAIL
ARM1:
ARMED=INP(&H3FE)
TEST=ARMED AND &B01000000
IF TEST=64 THEN GOTO ARM1
PRINT"COMMENCE SCREEN1 CAPTURE."
LOOK1:
DATAREADY=INP(&H3FD)
TEST=DATAREADY AND &B00000001
IF TEST=0 THEN GOTO LOOK1
N1=N1+1
DATARAW1(N1)=INP(&H3F8)
RI=INP(&H3FE)
TEST=RI AND &B01000000
IF TEST=0 THEN GOTO LOOK1
REM COMMENCE THE SECOND SCREEN CAPTURE
ARM2:
ARMED=INP(&H3FE)
TEST=ARMED AND &B01000000
IF TEST=64 THEN GOTO ARM2
PRINT"COMMENCE SCREEN2 CAPTURE."
LOOK2:
DATAREADY=INP(&H3FD)
TEST=DATAREADY AND &B00000001
IF TEST=0 THEN GOTO LOOK2
N2=N2+1
DATARAW2(N2)=INP(&H3F8)
RI=INP(&H3FE)
TEST=RI AND &B01000000
IF TEST=0 THEN GOTO LOOK2
PRINT"FINISHED CAPTURING SCREEN 1 AND SCREEN 2."
PRINT"SCALING CAPTURED DATA."
REM SCALE DATA TAKEN TO THE STANDARD 1024 POINTS.
OPEN PICNAME$ FOR OUTPUT AS #1
WRITE #1,STFREQ,SPANDIV,RESBW,DBDIV,SCREENTOP
FOR COUNTNUM=1 TO 1024
NN=INT(COUNTNUM*(N1/1024))
FINALDATA(COUNTNUM)=255-DATARAW1(NN)
NEXT COUNTNUM
FOR COUNTNUM=1 TO 1024
NN=INT(COUNTNUM*(N2/1024))
FINALDATA(COUNTNUM+1024)=255-DATARAW2(NN)
```

```
NEXT COUNTNUM
PRINT"STORING SCALED DATA TO HARD DISK."
FOR CNT=1 TO 2048
WRITE #1, FINALDATA(COUNTNUM)
NEXT CNT
CLOSE #1
PRINT"FINISHED WRITING FILE TO DISK."
RETURN
REM ***************************************************
DOITAGAIN:
REM ***************************************************
REM INCREMENT OBSERVATION FREQUENCY, SET NEW *.PIC FILENAME
REM AND PROMPT USER TO WAKE UP!
REM
REM INCREMENT SCREEN START FREQUENCY
STFREQ=STFREQ+(10*(SPANDIV/1000))
FILENUM=FILENUM+1
REM INCREMENT FILE SUFFIX BY ONE.
REM CONVERT FILENUM TO A STRING THEN GET RID OF THE LEADING SPACE.
FILENUM$=STR$(FILENUM)
FILENUM$=RIGHT$(FILENUM$,LEN(FILENUM$)-1)
PICNAME$=ROOT$+FILENUM$+".PIC"
REM
LARGENOSE:
PRINT"Capture program is ready for the next screen."
PRINT
PRINT"Hit 'Q' if you want to exit this observation session."
PRINT
PRINT"Otherwise, hit any other key to indicate that the spectrum analyzer "
PRINT"is set to a start frequency of";STFREQ;"MHz."
INPUT ZZ$
IF ZZ$="Q" THEN
PRINT
CLS
PRINT"Are you sure you want to quit?"
INPUT ZZZ$
IF ZZZ$="Y" THEN
SETFLAG=1
RETURN
ELSE
GOTO LARGENOSE
END IF
END IF
PRINT
PRINT"Are you sure that the spectrum analyzer is set to";STFREQ;"MHz."
INPUT ZZ$
IF ZZ$<>"Y" THEN
CLS
GOTO LARGENOSE
END IF
SETFLAG=0
RETURN
```

END

Appendix B - RECGNIZE.BAS

```
REM   SIGNAL IDENTIFICATION PROGRAM    RECGNIZE.BAS
REM   ERIC OIESEN    MAY 29, 1992    VIRGINIA TECH
REM   THIS PROGRAM IS INTENDED TO BE USED TO TAKE A
REM   GROUP OF 1024 POINTS WHICH REPRESENT A SPECTRUM ANALYZER
REM   OUTPUT AND IDENTIFY AND CATALOG SIGNALS WHICH EXIST.
REM   THESE SIGNALS WILL BE DATA (NYQUIST FILTERED) OR FM.
REM   THIS PROGRAM WILL ACCEPT *.PIC FILES FROM AN OBSERVATION SESSION
REM   AND PRODUCE *.DAT FILES WHICH CONTAIN THE OBSERVATION REPORT.
REM   THE OBSERVATION REPORT LISTS SIGNALS WITH THEIR CENTER FREQUENCY,
REM   BANDWIDTH, AND DESIGNATION.
REM   THE RECOGNITION SUBROUTINES EXPECT 200 kHz SPAN/DIV, 30 kHz RESBW,
REM   AND 10 dB/DIV.
REM
REM
REM MAIN PROGRAM
REM DEFINE VARIABLES
DIFF1=20:FILENUM=1:REF=111.5:HREF=126.5:FILENUM1=0
ROOTPIC$="TEST":ROOTDAT$="OUT"
INNAME$="TEST.PIC":OUTNAME$="OUTPUT.DAT"
1 DIM SPECDATA1(0:10000),ZERODATA(0:10000),SPECDATA2(0:10000)
DIM ZXSTACK%(1000),SLOPE%(1000),SIG%(1000,2),BWHZ(500),CFREQHZ(500)
DIM IDENTIFY$(500),SPIKESTACK(500),CNR(500),BUCKET(256)
START:
REM INITIAL SETUP SCREEN
GOSUB 8000
BEGIN:
REM ADJUST FILENAMES FOR PROCESSING
GOSUB FILEINC
REM LOAD FILE FOR PROCESSING
GOSUB READPIC
REM ESTABLISH NOISEFLOOR
GOSUB HISTNOISE
REM LOOK FOR ZERO CROSSINGS AND SLOPE
GOSUB 4000
REM PAIRS OF OPPOSING SLOPE (+ THEN -) CONSTITUTE A SIGNAL
GOSUB 6000
REM CATALOG AS DATA OR SPIKE BY BANDWIDTH
GOSUB 7000
REM IF A SPIKE, VSAT OR FSK COMPARISON AGAINST SECOND SCREEN.
GOSUB COMPSCREEN
REM COMPSCREEN DOESN'T PROVIDE AN ERROR FREE DETERMINATION OF VSAT OR FM.
REM SPACING SUBROUTINE.  FINDS SPACING OF SPIKES AND GROUPS THEM.
GOSUB SPACING
REM USE SPACING INFORMATION TO AVERAGE TOGETHER MEAN DIFFERENCES.
GOSUB AVGMEAN
REM LOG AND CATALOG DATA.
GOSUB 9000
REM INCREMENT FILENUM AND CHECK FOR END OF FILE DIGESTION.
FILENUM=FILENUM+1
IF FILENUM>FILETOTAL THEN
CLS
PRINT"File digestion complete.  Burp."
```

```
PRINT"Hit any key to continue."
INPUT ZZ$
CLOSE #4
GOTO START
END IF
GOTO BEGIN
END
REM ****************************************************
FILEINC:
REM ****************************************************
REM
REM INCLUDE FILENUM WITH .PIC AND .DAT FILENAMES.
FILENUM$=STR$(FILENUM)
FILENUM$=RIGHT$(FILENUM$,LEN(FILENUM$)-1)
PICNAME$=ROOTPIC$+FILENUM$+".PIC"
DATNAME$=ROOTDAT$+FILENUM$+".DAT"
REM
RETURN
REM ****************************************************
READPIC:
REM ****************************************************
PNTCNT=0
FILESTART=FILENUM
LOADFILE:
OPEN PICNAME$ FOR INPUT AS #2
INPUT #2,STFREQ,SPANDIV,RESBW,DBDIV,SCREENTOP
IF FILENUM=1 THEN
STARTFRQ=STFREQ
END IF
IF PNTCNT=0 THEN
        GROUPFREQ=STFREQ
END IF
IF (1023+PNTCNT)>10000 THEN
PRINT"TOO MANY SIGNAL OVERLAPS.  POINT ARRAY FULL."
PRINT"THIS WILL RESULT IN AN ERROR IN THE DATA FILE."
PRINT"A SIGNAL WILL PROBABLY BE MISSED IN ";PICNAME$"."
INPUT"HIT ANY KEY TO CONTINUE.";ZZ$
CLOSE #2
FILENUM=FILENUM-1
FILESTOP=FILENUM
RETURN
END IF
FOR ZZ=PNTCNT TO 1023+PNTCNT
INPUT #2, SPECDATA1(ZZ)
NEXT ZZ
FOR ZZ=PNTCNT TO 1023+PNTCNT
INPUT #2, SPECDATA2(ZZ)
NEXT ZZ
IF SPECDATA1(1023+PNTCNT)>REF THEN
PNTCNT=PNTCNT+1024
FILENUM=FILENUM+1
GOSUB FILEINC
```

```
CLOSE #2
GOTO LOADFILE
END IF
CLOSE #2
FILESTOP=FILENUM
RETURN
REM ******************************************************
HISTNOISE:
REM ******************************************************
LOWEST=SPECDATA1(0)
HIGHEST=SPECDATA1(0)
REM BUCKET NEEDS TO BE INITIALIZED
FOR ZZ=0 TO 256
BUCKET(ZZ)=0
NEXT ZZ
FOR ZZ=0 TO 1023
IF (SPECDATA1(ZZ)<LOWEST) THEN
LOWEST=SPECDATA1(ZZ)
END IF
IF (SPECDATA1(ZZ)>HIGHEST) THEN
HIGHEST=SPECDATA1(ZZ)
END IF
REM NOW PERFORM HISTOGRAM.  COUNT THE NUMBER OF TIMES A PARTICULAR
REM VALUE OCCURS.  SPECDATA1 VARIES BETWEEN 0 AND 255.
BUCKET(SPECDATA1(ZZ))=BUCKET(SPECDATA1(ZZ))+1
NEXT ZZ
REM
REM NOW FIND NOISEFLOOR.  START AT THE AVERAGE BETWEEN THE MAX AND MIN
REM AND SEARCH DOWN TO FIND THE BIGGEST BUCKET.  THAT VALUE WILL BE
REM CONSIDERED THE NOISEFLOOR.
REM
MIDL=INT((HIGHEST+LOWEST)/2)
NOISEFLR=0
REM ZZ SHOULD SPAN 0 TO 255
BIGBUCKET=BUCKET(0)
FOR ZZ=0 TO MIDL
IF (BUCKET(ZZ)>BIGBUCKET) THEN
NOISEFLOOR=ZZ
BIGBUCKET=BUCKET(ZZ)
END IF
NEXT ZZ
REF=NOISEFLOOR+10.5
HREF=REF+8.5
RETURN
REM ******************************************************
4000 REM LOOK FOR ZERO CROSSINGS AND SLOPE
REM ******************************************************
REM POINT 1024 IS THE START OF THE SECOND SCREEN.
REM SET SLOPE AND ZX INDEX TO 0
ZX=0
REM LOOK FOR ZERO CROSSINGS (LOOK FOR CHANGE IN SIGN) AND
REM CATALOG SLOPE
```

```
ZERODATA(0)=SPECDATA1(0)-REF
FOR ZZ=1 TO 1023+PNTCNT
ZERODATA(ZZ)=SPECDATA1(ZZ)-REF
REM POSITIVE SLOPE
IF (ZERODATA(ZZ)=>0) AND (ZERODATA(ZZ-1)<0) THEN
ZX=ZX+1
ZXSTACK%(ZX)=ZZ-1
SLOPE%(ZX)=1
GOTO 4500
END IF
REM NEGATIVE SLOPE
IF (ZERODATA(ZZ)<=0) AND (ZERODATA(ZZ-1)>0) THEN
ZX=ZX+1
ZXSTACK%(ZX)=ZZ
SLOPE%(ZX)=0
GOTO 4500
END IF
4500 REM THIS IS THE BEST OF TIMES; THIS IS THE WORST OF TIMES.
NEXT ZZ
RETURN
REM ****************************************************
6000 REM PAIR ZERO CROSSINGS TO FIND SIGNAL
REM ****************************************************
REM LOOK FOR + SLOPE THEN - SLOPE
REM ZS IS THE NUMBER OF SIGNALS
ZS=0
REM NOISE FILTER
FOR ZC=1 TO ZX-1
REM HAVE SIGNAL, NOW LOOK TO SEE IF IT PIERCES HREF
IF (SLOPE%(ZC)=1) AND (SLOPE%(ZC+1)=0) THEN
FOR COUNT1=ZXSTACK%(ZC) TO ZXSTACK%(ZC+1)
IF (SPECDATA1(COUNT1)>HREF) THEN
ZS=ZS+1
SIG%(ZS,1)=ZXSTACK%(ZC)
SIG%(ZS,2)=ZXSTACK%(ZC+1)
GOTO NEXTPAIR
END IF
NEXT COUNT1
END IF
NEXTPAIR:
NEXT ZC
REM
RETURN
REM ****************************************************
7000 REM FIND BW, CENTER FREQ., AND C/N
REM ****************************************************
REM BW IS DEFINED AS THE DISTANCE FROM ONE ZERO CROSSING TO THE NEXT
REM BWHZ IS IN KHZ; CFREQ, MHZ.
FACTOR=((SPANDIV/100)/1.023)
FACTOR2=((SPANDIV/100)/1023)
N=0
FOR ZBW=1 TO ZS
```

```
BW=SIG%(ZBW,2)-SIG%(ZBW,1)
BWHZ(ZBW)=BW*FACTOR
REM TEST FOR SPIKES OR NO SPIKES
IF (BWHZ(ZBW)<70) THEN
N=N+1
SPIKESTACK(N)=ZBW
ELSE
       IDENTIFY$(ZBW)="FSK"
IF BWHZ(ZBW)<72 THEN IDENTIFY$(ZBW)="PSK*"
END IF
CFREQHZ(ZBW)=(FACTOR2*((BW/2)+SIG%(ZBW,1)))+GROUPFREQ
REM FIND C/N.  C IS FOUND USING SIMPSON'S RULE.  N IS TAKEN TO BE CONSTANT
REM Simpson's rule for integration
REM CALCULATE CARRIER POWER
SIMPSON:
REM SIMPSON'S RULE OPERATES ON 0 TO N POINTS WHERE N IS EVEN.
REM DETERMINE IF THE NUMBER OF POINTS MEETS THE ABOVE CRITERION.
TEST=CSNG(SIG%(ZBW,2)-SIG%(ZBW,1))
FRAC1=(TEST/2)-FIX(TEST/2)
FRAC2=((TEST+1)/2)-FIX((TEST+1)/2)
IF FRAC1>FRAC2 THEN
FREQBEGIN=SIG%(ZBW,1)+1
ELSE
FREQBEGIN=SIG%(ZBW,1)
        END IF
        FREQEND=SIG%(ZBW,2)
        SUMODD#=0:SUMEVEN#=0:SUMEND#=0
REM FACTOR TO CONVERT POINTS TO dB. IN EACH CASE, SCREENTOP
REM MUST BE TAKEN INTO ACCOUNT.
PTSDB=(80/255)
SUMEND#=10^(.1*CDBL(SCREENTOP-PTSDB*(255-SPECDATA1(FREQEND))))+_
10^(.1*CDBL(SCREENTOP-PTSDB*(255-SPECDATA1(FREQBEGIN))))
FOR K=FREQBEGIN+1 TO FREQEND STEP 2
  SUMODD#=SUMODD#+(10^(.1*CDBL(SCREENTOP-PTSDB*(255-SPECDATA1(K)))))
NEXT K
FOR K=FREQBEGIN+2 TO FREQEND-2 STEP 2
  SUMEVEN#=SUMEVEN#+(10^(.1*CDBL(SCREENTOP-PTSDB*(255-SPECDATA1(K)))))
NEXT K
H=1
SIGNALPOWER#=H*(SUMEND#+4*SUMODD#+2*SUMEVEN#)/3
NOISEPOWER#=CDBL(FREQEND-FREQBEGIN)*_
           (10^(.1*CDBL(SCREENTOP-PTSDB*(255-NOISEFLOOR))))
        CN=CSNG(SIGNALPOWER#/NOISEPOWER#)
CNR(ZBW)=10*LOG10(CN)
REM CN IS NOW IN dBm.
REM CONVERT TO dBm (POINTS ARE ALREADY dB).
'PRINT SIGNALPOWER#,NOISEPOWER#
'PRINT SUMEVEN#,SUMODD#,SUMEND#
'PRINT CN,CNR(ZBW)
'INPUT ZZ$
'PRINT ZBW,CFREQHZ(ZBW),BWHZ(ZBW),IDENTIFY$(ZBW)
NEXT ZBW
```

```
'INPUT ZZ$
RETURN
REM *****************************************************
SPACING:
REM *****************************************************
REM THIS SUBROUTINE FINDS SPIKE DELTA CENTER FREQUENCY AND THEN GROUPS SPIKES
REM ACCORDINGLY.
DIM DELTACFHZ(200),STARTSIG(200),ENDSIG(200)
FOR DUM=1 TO 200
STARTSIG(DUM)=0
ENDSIG(DUM)=0
DELTACFHZ(DUM)=0
NEXT DUM
REM CNT IS THE SPIKE NUMBER
FOR CNT=1 TO N-1
DELTACFHZ(CNT)=CFREQHZ(SPIKESTACK(CNT+1))-CFREQHZ(SPIKESTACK(CNT))
NEXT CNT
REM SORT OUT GROUPS
CNT=0
ZZ=0
REGSPACING=.08
SODA:
CNT=CNT+1
IF CNT>N-1 THEN GOTO SODA3
REM DETERMINE IF REGULAR SPACING IS PRESENT.
IF DELTACFHZ(CNT)>REGSPACING THEN
GOTO SODA
REM IF REGULAR SPACING IS PRESENT, MARK THE BEGINNING.
ELSE
ZZ=ZZ+1
STARTSIG(ZZ)=CNT
SODA2:
CNT=CNT+1
          IF CNT>N THEN
          IF ENDSIG(ZZ)=0 THEN
          ENDSIG(ZZ)=N
          END IF
          GOTO SODA3
          END IF
IF DELTACFHZ(CNT)<REGSPACING THEN GOTO SODA2
END IF
REM SPACING CRITERIA ISN'T MET SO MARK END OF GROUP.
ENDSIG(ZZ)=CNT
IF CNT<N THEN GOTO SODA
SODA3:
REM
'REM TEST LINES
'FOR CNT=1 TO ZZ
'         PRINT CNT,STARTSIG(CNT),ENDSIG(CNT)
'NEXT CNT
'INPUT ZZ$
RETURN
```

```
REM ***************************************************
AVGMEAN:
REM ***************************************************
REM THIS SUBROUTINE CALCULATES THE AVERAGE MEAN DIFFERENCE FOR A GROUP.
REM GROUPING IS DECIDED IN THE SPACING SUBROUTINE.
FOR CNT=1 TO ZZ
SUM=0
IF ENDSIG(CNT)=0 THEN GOTO LATER
FOR CNT2=STARTSIG(CNT) TO ENDSIG(CNT)
SUM=SUM+DIFF(CNT2)
NEXT CNT2
AVGDIFF(CNT)=SUM/(ENDSIG(CNT)-STARTSIG(CNT)+1)
'PRINT CNT,AVGDIFF(CNT)
NEXT CNT
LATER:
'INPUT ZZ$
'CLS
REM QUALIFY GROUP BY ITS MEAN
FOR CNT=1 TO ZZ
IF ENDSIG(CNT)=0 THEN GOTO LATER2
IF AVGDIFF(CNT)<DIFF1 THEN
IF AVGDIFF(CNT)<(DIFF1-3) THEN
DUMMY$="NBND GRP"
ELSE
DUMMY$="NBND GRP*"
END IF
ELSE
IF AVGDIFF(CNT)>(DIFF+3) THEN
DUMMY$="VSAT"
ELSE
DUMMY$="VSAT*"
END IF
END IF
FOR CNT2=STARTSIG(CNT) TO ENDSIG(CNT)
IDENTIFY$(SPIKESTACK(CNT2))=DUMMY$
NEXT CNT2
NEXT CNT
LATER2:
RETURN
REM *****************************************************
COMPSCREEN:
REM *****************************************************
REM THIS SUBROUTINE IMPLEMENTS THE VSAT SEARCH.
REM IT COMPARES SCREEN 1 SPIKES TO THE SAME PLACE IN SCREEN 2.
REM
REM SPIKECNT IS THE SPIKE NUMBER.  SPIKESTACK(N) IS THE SIGNAL NUMBER.
DIM DIFF(200)
CLS
FOR SPIKECNT=1 TO N
SUM=0
FOR SKIRTCNT=SIG%(SPIKESTACK(SPIKECNT),1) TO SIG%(SPIKESTACK(SPIKECNT),2)
     SUM=SUM+ABS(SPECDATA1(SKIRTCNT)-SPECDATA2(SKIRTCNT))
```

```
NEXT SKIRTCNT
DIFF(SPIKECNT)=SUM/(SIG%(SPIKESTACK(SPIKECNT),2)-SIG%(SPIKESTACK(SPIKECNT),1))
IF DIFF(SPIKECNT)>DIFF1 THEN
IDENTIFY$(SPIKESTACK(SPIKECNT))="VSAT"
ELSE
IDENTIFY$(SPIKESTACK(SPIKECNT))="POTENTIAL CARRIER"
END IF
'PRINT SPIKECNT,DIFF(SPIKECNT),IDENTIFY$(SPIKESTACK(SPIKECNT))
NEXT SPIKECNT
'INPUT ZZ$
RETURN
REM ******************************************************
9000 REM LOG AND CATALOG DATA
REM ******************************************************
REM FILE FORMAT
REM START FREQ.(MHz),RESOLUTION BW (kHz),SPAN/DIV(kHz),
REM NUMBER OF SIGNALS, REFERENCE LEVEL, INPUT FILENAME.
REM ARE ON THE FIRST LINE.  EACH SUCCEEDING LINE HAS SIG #, CENTER FREQ.,
REM BANDWIDTH, IDENTIFICATION TAG, AND C/N.
REM SINCE THE FILE WHICH GENERATED
REM THE PLOT DATA FILE CAN BE EXAMINED, THE USER CAN DOUBLE CHECK
REM FALSE SIGNALS.
IF ZS=0 THEN
ZS=1
IDENTIFY$(1)="NO SIGNALS FOUND."
CFREQHZ(1)=0:BWHZ(1)=0
END IF
FILECURRENT=FILENUM:NUMOLD=0:NUM=0
FOR CNT=FILESTART TO FILESTOP
FILENUM=CNT
        GOSUB FILEINC
        REM THIS LOOP RE-ESTABLISHES WHICH DATA BELONGS TO WHICH SCREEN
FOR CNT1=(1+NUMOLD) TO ZS
        IF CFREQHZ(CNT1)>(STARTFRQ+2*FILENUM) THEN GOTO SCHMUCK
                NUM=NUM+1
        NEXT CNT1
SCHMUCK:
OPEN DATNAME$ FOR OUTPUT AS #3
STFREQ=STARTFRQ+2*(FILENUM-1)
WRITE #3,STFREQ,RESBW,SPANDIV,(NUM-NUMOLD),REF
WRITE #3,PICNAME$
PRINT "WRITING ";DATNAME$;" TO DISK."
FOR ZLOG=(NUMOLD+1) TO NUM
      CNT2=ZLOG-NUMOLD
      WRITE #3,CNT2,CFREQHZ(ZLOG),BWHZ(ZLOG),IDENTIFY$(ZLOG),CNR(ZLOG)
      WRITE #4,ZLOG,CFREQHZ(ZLOG),BWHZ(ZLOG),IDENTIFY$(ZLOG),CNR(ZLOG)
NEXT ZLOG
NUMOLD=NUM
CLOSE #3
NEXT CNT
FILENUM=FILECURRENT
RETURN
```

```
REM ******************************************************
8000 REM SETUP SCREEN
REM ******************************************************
SCREEN 0
8010 CLS
PRINT"                                 RECOGNITION PROGRAM"
PRINT"                SETUP SCREEN - TYPE THE NUMBER OF THE SELECTION FOR ACCESS."
PRINT
PRINT"1.  FILE NAME ROOT (INPUT)   ";ROOTPIC$
PRINT"2.  FILE NAME ROOT (OUTPUT)  ";ROOTDAT$
PRINT"3.  ZERO CROSS LEVEL         ";REF
PRINT"4.  SPURIOUS LEVEL           ";HREF
PRINT"5.  VSAT/FM LEVEL            ";DIFF1
PRINT"6.  FILE NAME (PLOT/DIS)     ";ROOT$
PRINT"7.  SESSION FILE NAME        ";SESSION$
PRINT"8.  FORWARD PLOT REVIEW      "
LOCATE 13,1
PRINT"Analyze data    - R."
PRINT"Display results - D."
PRINT"Graph screen 1  - G1."
PRINT"Graph screen 2  - G2."
PRINT"DIR *.PIC       - P."
PRINT"DIR *.DAT       - T."
PRINT"To quit, type Q."
PRINT
PRINT"This program isn't idiot-proof.  Don't write over your data!"
INPUT ZZ$
IF ZZ$="1" THEN
LOCATE 22
CHOOSEROOTPIC:
INPUT"Input new FILE NAME ROOT (INPUT)";ROOTPIC$
IF LEN(ROOTPIC$)>4 THEN
PRINT"FILE NAME ROOT is too long.  Choose again."
LOCATE 24
GOTO CHOOSEROOTPIC
END IF
GOTO 8010
END IF
IF ZZ$="2" THEN
LOCATE 22
CHOOSEROOTDAT:
INPUT"Input new FILE NAME ROOT (OUTPUT)";ROOTDAT$
IF LEN(ROOTDAT$)>4 THEN
PRINT"FILE NAME ROOT is too long.  Choose again."
LOCATE 24
GOTO CHOOSEROOTDAT
END IF
GOTO 8010
END IF
IF ZZ$="3" THEN
LOCATE 22
INPUT"Input new ZERO CROSS LEVEL ";REF
```

```
GOTO 8010
END IF
IF ZZ$="6" THEN
LOCATE 22
INPUT"Input new FILE NAME (PLOT/DIS)";ROOT$
INNAME$=ROOT$+".PIC"
OUTNAME$=ROOT$+".DAT"
GOTO 8010
END IF
IF ZZ$="4" THEN
LOCATE 22
INPUT"Input new HREF ";HREF
GOTO 8010
END IF
IF ZZ$="5" THEN
LOCATE 22
INPUT"Input new VSAT/FM level";DIFF1
GOTO 8010
END IF
IF ZZ$="7" THEN
LOCATE 22
INPUT"Input new SESSION FILE NAME";SESSION$
OPEN SESSION$ FOR OUTPUT AS #4
GOTO 8010
END IF
IF ZZ$="B" THEN
        FILENUM1=FILENUM1+1
FILENUM$=STR$(FILENUM1)
FILENUM$=RIGHT$(FILENUM$,LEN(FILENUM$)-1)
INNAME$=ROOT$+FILENUM$+".PIC"
CALL GRAPH(INNAME$,1023,REF,HREF)
GOTO 8010
END IF
IF ZZ$="R" THEN
CLS
PRINT"Input number of files to be eaten."
INPUT FILETOTAL
RETURN
END IF
IF ZZ$="Q" THEN
CLS
INPUT"Are you sure that you want to quit? (Y)";ZZ$
IF ZZ$="Y" THEN
PRINT"Program concluded at user's request."
END
END IF
END IF
IF ZZ$="D" THEN
CLS
        CALL DISPLAY(OUTNAME$)
END IF
IF ZZ$="G1" THEN
```

```
CLS
CALL GRAPH(INNAME$,1023,REF,HREF)
END IF
IF ZZ$="G2" THEN
CLS
CALL GRAPH(INNAME$,2047,REF,HREF)
END IF
IF ZZ$="P" THEN
CLS
FILES"*.PIC"
LOCATE 21,1:PRINT"Hit return to continue."
INPUT Q$
END IF
IF ZZ$="T" THEN
CLS
FILES"*.DAT"
LOCATE 21,1:PRINT"Hit return to continue."
INPUT Q$
END IF
GOTO 8010
REM ******************************************************
SUB DISPLAY(OUTNAME$)
REM ******************************************************
LOCAL STFREQ,RESBW,SPANDIV,NUM,CFREQHZ(),BWHZ(),ZLOG,IDENTIFY$,REFLEV
LOCAL SCR,ZLOG(),A$,I,BLU,INNAME$
DIM CFREQHZ(500),BWHZ(500),ZLOG(500),IDENTIFY$(500),CNR(500)
A$="#####.##":B$="##.#"
SCREEN 0,0,0,0
OPEN OUTNAME$ FOR INPUT AS #4
INPUT #4,STFREQ,RESBW,SPANDIV,NUM,REFLEV
INPUT #4,INNAME$
FOR I=1 TO NUM
INPUT #4,ZLOG(I),CFREQHZ(I),BWHZ(I),IDENTIFY$(I),CNR(I)
NEXT I
CLOSE #4
CLS
PRINT TAB(20) "FILENAME = ";OUTNAME$;" from ";INNAME$
PRINT"START FREQ (MHz)";:PRINT USING A$;STFREQ;
PRINT"  SPAN/DIV (kHz)";:PRINT USING A$;SPANDIV;
PRINT"  RES BW (kHz)";:PRINT USING A$;RESBW
PRINT TAB(29) "REFERENCE LEVEL =";REFLEV
PRINT
PRINT"SIG NUM" TAB(11) "CNTR FREQ(MHz)" TAB(29) "BW (kHz)";
PRINT TAB(43) "C/N (dB)" TAB(58) "SIGNAL TYPE"
SCR=1
10100   BLU=SCR*17
LOCATE 6,1
FOR I=(1+(SCR-1)*17) TO BLU
IF (I<NUM+1) THEN
PRINT TAB(3) ZLOG(I);:PRINT TAB(12);:PRINT USING A$;CFREQHZ(I);
PRINT TAB(27);:PRINT USING A$;BWHZ(I);:PRINT TAB(44)
PRINT USING B$;CNR(I);:PRINT TAB(58) IDENTIFY$(I)
```

```
ELSE
PRINT"
END IF
NEXT I
IF BLU>NUM THEN
 GOTO 10110
END IF
LOCATE 23,1
INPUT"Press any key to see more";ZZ$
SCR=SCR+1
GOTO 10100
10110 REM NOTHING MEANS NOTHING
LOCATE 23,1
INPUT"Press any key to return to menu";ZZ$
END SUB
REM ************
SUB GRAPH(INNAME$,PIC,REF,HREF)
REM ************
LOCAL YAXIS(),X,XX,YY,STFREQ,SPANDIV,RESBW,DBDIV,SCREENTOP,A$
DIM YAXIS(2050)
OPEN INNAME$ FOR INPUT AS #5
CLS
A$="####.##"
REM SCREEN 10 WORKS AT HOME
REM THIS IS THE NUMBER FOR EGA MONOCHROME GRAPHICS
REM LUNCHBOX PUKES ON SCREEN 10.
REM LUNCHBOX LIKES 11 BUT THE GRAPH SCALING IS SCREWED UP.
REM GRAPH SCALING PRESENTLY SET TO WORK WITH SCREEN 10.
SCREEN 10
WINDOW (-100,-60)-(1100,270)
REM READ IN DATA POINTS
INPUT #5,STFREQ,SPANDIV,RESBW,DBDIV,SCREENTOP
SPANDIV=SPANDIV/1000
FOR X=0 TO PIC
INPUT #5,YAXIS(X)
NEXT X
CLOSE #5
REM SCALE TO LOOK AT SCREEN 2
IF PIC=2047 THEN
FOR X=0 TO 1023
YAXIS(X)=YAXIS(X+1024)
NEXT X
END IF
REM PRINT Y-AXIS MARKER
LOCATE 2,3:PRINT SCREENTOP:LOCATE 2,76:PRINT"255"
LOCATE 6,3:PRINT SCREENTOP-2*DBDIV:LOCATE 6,76:PRINT"191"
LOCATE 11,3:PRINT SCREENTOP-4*DBDIV:LOCATE 11,76:PRINT"127"
LOCATE 16,3:PRINT SCREENTOP-6*DBDIV:LOCATE 16,76:PRINT"63"
LOCATE 21,3:PRINT SCREENTOP-8*DBDIV:LOCATE 21,76:PRINT"0"
LOCATE 8,2:PRINT"dBm"
REM PLOT GRIDLINES
REM BOX
```

```
LINE(0,0)-(0,255)
LINE(0,0)-(1023,0)
LINE(0,255)-(1023,255)
LINE(1023,255)-(1023,0)
REM PRINT HEADER
LOCATE 1,1
PRINT TAB(37) INNAME$
REM X-AXIS LINES
FOR X=1 TO 10
XX=X*102.3
LINE(XX,0)-(XX,255)
NEXT X
REM PLOT REF AND HREF USING DASHED LINES
FOR X=1 TO 1022 STEP 10
LINE(X,REF)-(X+2,REF)
LINE(X,HREF)-(X+2,HREF)
NEXT X
REM Y-AXIS LINES
FOR X=1 TO 8
YY=X*(255/8)
LINE(0,YY)-(1023,YY)
NEXT X
REM PLOT POINTS
FOR X=0 TO 1022
LINE(X,YAXIS(X))-((X+1),YAXIS(X+1))
NEXT X
REM PRINT X AXIS MARKERS
LOCATE 22,1
'FOR XX=0 TO 7
'FOR X=1 TO 9 STEP 2
'        X$=STR$(X)
'        PRINT X$;
'NEXT X
'NEXT XX
PRINT TAB(5);:PRINT USING A$;STFREQ;:PRINT TAB(18);
PRINT USING A$;STFREQ+2*SPANDIV;:PRINT TAB(32);
PRINT USING A$;STFREQ+4*SPANDIV;:PRINT TAB(46);
PRINT USING A$;STFREQ+6*SPANDIV;:PRINT TAB(60);
PRINT USING A$;STFREQ+8*SPANDIV;:PRINT TAB(71);
PRINT USING A$;STFREQ+10*SPANDIV;
PRINT TAB (33)"FREQUENCY IN MHz"
LOCATE 24,78
INPUT ZZ$
SCREEN 0
CLS
END SUB
REM ******************************************************
```

Vita

Eric Andrew Oiesen was born in Oil City, Pennsylvania on November 9, 1966. He has lived in Virginia since 1973. He graduated from Stuarts Draft High School in 1985. He entered Virginia Tech in 1985 and obtained his BSEE (Magna Cum Laude) in 1990. During his undergraduate work, he held a co-op position with the Transmission Processing Department of COMSAT Labs in Clarksburg, MD. He entered the graduate program in electrical engineering at Virginia Tech in 1990. During his first year as a graduate student, he worked as a graduate teaching assistant. Eric will commence employment with Varian Microwave Equipment Products in Santa Clara, CA in September 1992.