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16. Abstract

This study investigated the use of slow scan television for vehicular traffic surveillance as an alternative to normal, real time TV. Slow scan television typically utilizes a limited bandwidth communication channel for the transmission of video image data. The transmission medium generally considered in this study is a telephone line passing digital information at 9600 bits per second, but other transmission mediums would serve the same purpose. Slow scan television systems have been available for many years, but have enjoyed only limited appeal. Image transmission times from 1 to 2 minutes are frequently cited, and the resulting time lapses seem to discourage many applications, including traffic surveillance. A large number of slow scan references were reviewed and are cited in the reference lists and bibliography. A comprehensive description of the principal slow scan equipment needed for traffic surveillance is given, together with cost data. The advantages and disadvantages of slow scan are cited, and alternatives are presented for enhancing the scan rate. Methods of image data compression are discussed, and particular attention is paid to the pilot project of the Maryland Department of Transportation, where new, high technology techniques were utilized in compressed television transmission (CTT) equipment in a traffic surveillance application. Additional tests were conducted during the course of this study to determine the sensitivity of the CTT equipment to varying light conditions, camera jitter, and viewing angles. Equipment needs and techniques for the special requirements of traffic surveillance are discussed, and cost figures are included. A microcomputer system is recommended for the needs of traffic surveillance for incident detection. The study conclusions are basically in favor of slow scan television where limited bandwidth data transmission is a necessity, but the scan rate should approach 1 second intervals to meet the general needs of traffic surveillance.

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EVALUATION OF SLOW SCAN TELEVISION FOR TRAFFIC CONDITION MONITORING

by

Charles W. Blumentritt

Research Report 398-1F
Research Study Number 2-18-84-398

Sponsored by the Texas
State Department of Highways and Public Transportation
In cooperation with the
U. S. Department of Transportation
Federal Highway Administration

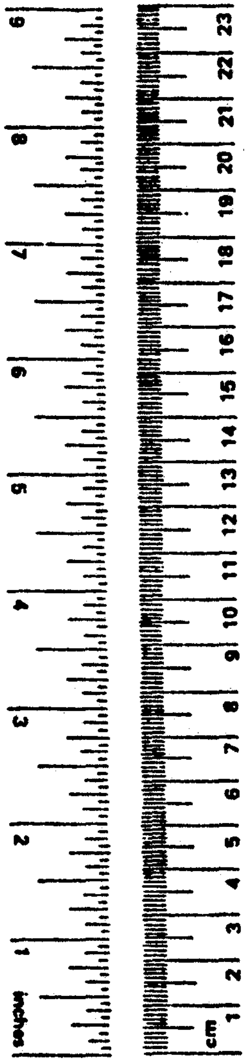
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

December 1985

METRIC CONVERSION FACTORS

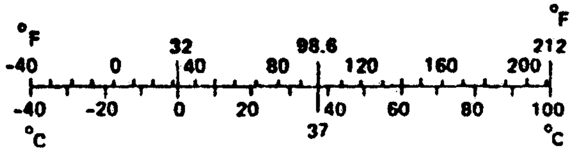
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

SUMMARY

This study investigated the use of slow scan television for vehicular traffic surveillance as an alternative to normal, real time TV. Slow scan television typically utilizes a limited bandwidth communication channel for the transmission of video image data. The transmission medium generally considered in this study is a telephone line passing digital information at 9600 bits per second, but other transmission mediums would serve the same purpose.

Slow scan television systems have been available for many years, but have enjoyed only limited appeal. Image transmission times from 1 to 2 minutes are frequently cited, and the resulting time lapses seem to discourage many applications, including traffic surveillance. In a traffic control and surveillance system, image data must be refreshed at a rate that is consistent with the objective of the observer, and his attendant response requirements.

A large number of slow scan references were reviewed and are cited in the reference lists and bibliography. A comprehensive description of the principal slow scan equipment needed for traffic surveillance is given, together with cost data. The advantages and disadvantages of slow scan are cited, and alternatives are presented for enhancing the scan rate.

Methods of image data compression are discussed, and particular attention is paid to the pilot project of the Maryland Department of Transportation, where new, high technology techniques were utilized in compressed television transmission (CTT) equipment in a traffic surveillance application. Additional tests were conducted during the course of this study to determine the sensitivity of the CTT equipment to varying light conditions, camera jitter, and viewing angles.

Equipment needs and techniques for the special requirements of traffic surveillance are discussed, and cost figures are included. A microcomputer system is recommended for the needs of traffic surveillance for incident detection.

The study conclusions are basically in favor of slow scan television where limited bandwidth data transmission is a necessity, but the scan rate should approach 1 second intervals to meet the general needs of traffic surveillance.

Research Implementation

This study recommends the use of slow scan television for traffic surveillance where a limited bandwidth data transmission link must be utilized, such as a telephone line. Such a situation occurs when a relatively temporary installation is required, or when the high cost of a high bandwidth data transmission link (such as microwave, fiber optics, or coaxial cable) overshadows the need for television surveillance.

A new approach to slow scan equipment is presented in this report, primarily consisting of the use of general purpose microcomputers. The programming of these computers to meet the special needs of traffic surveillance would essentially convert slow scan television to fast scan television. It is recommended that sites meeting the requirements of conventional slow scan television monitoring be implemented with the equipment and techniques cited in this report.

DISCLAIMER

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the State Department of Highways and Public Transportation. This report does not constitute a standard, specification, or regulation.

PATENTS

There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new and useful improvement thereof, or any variety of plant wich is or may be patentable under the patent laws of the United States of America or any foreign country.

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Project.; to Mr. Fred White, Texas Transportation Institute (TTI) Librarian, for untiring effort in acquiring reference documents; to Ms. Carol Ryan of Vicon Industries for product literature; to Mr. Bob Rubish of Robot Research for product information; to Mr. Brad Houser of the Jet Propulsion Laboratory for documents and information on compressed television transmission; to Mr. Scott MacCalden of the California Department of Transportation, for information on Caltrans traffic surveillance activities; to Messers Steve Levine and Sonny Wong of the Texas Highway Department District 12, for their assistance in coordinating and implementing the use of a bucket truck for freeway operation videotaping, and for the loan of video recording and playback equipment; to Mr. Steve Payne of the Houston Metropolitan Transit Authority (MTA), for coordinating the use of MTA's television surveillance equipment and assistance in obtaining night traffic scenes using a low light level camera; to Messers Dick McCasland and Gene Ritch of the Houston TTI office, for their assistance in coordination, equipment acquisition, and videotaping of traffic scenes in Houston; to Mr. Bob Hodge and Ms. Poonam Wiles of the Texas Highway Department District 2, for information on the Fort Worth, Texas traffic surveillance and control project.

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CHAPTER 1

INTRODUCTION

Many phases of traffic operations have a need for visual monitoring, either by site visit or television surveillance. With the limited means for accommodating a large number of site visits, television monitoring can offer some alternative to field visits. Unfortunately, the communication bandwidth for television pictures is very wide, requiring coaxial cable, fiber optics or microwave facilities. Thus, a surveillance system is costly to install and maintain, with little provision for portability. A conventional television surveillance layout is shown in Figure 1.

Slow scan television, while sacrificing a continuous image, does offer many other advantages for traffic surveillance. It has a fair degree of portability, and utilizes a standard telephone line for the communication link. Consequently, installation is much less costly and more convenient. For many applications, such as freeway and intersection surveillance, HOV lane monitoring, etc., the time lapse images are adequate for operational monitoring. A typical slow scan television layout is shown in Figure 2.

1.1 Background

The still image is universally used for person to person communications. This is true of the printed page, photography, and even television. A variety of slow scan TV picture transmission systems have been developed over the last two decades; however, the present trend is to use conventional closed circuit television (CCTV) cameras, monitors, and other system components in conjunction with "scan conversion" devices which reduce the bandwidth of a CCTV camera output from a nominal five megahertz to approximately one kilohertz for transmission over voice grade circuits. This is a compression ratio of 5000 to 1, and is generally achieved by a) stretching out the signal in time from 30 pictures per second to an order of one picture in 100 seconds, and b) sacrificing some resolution in the final image.

The slowness of the picture transmission means that a second scan converter with a video memory must be used at the viewing location in order to rebuild clear, flicker-free signals in standard TV format. Once reconverted, the picture may be treated as conventional CCTV and monitored, switched, recorded, or otherwise handled for the user's convenience.

CONVENTIONAL SYSTEM

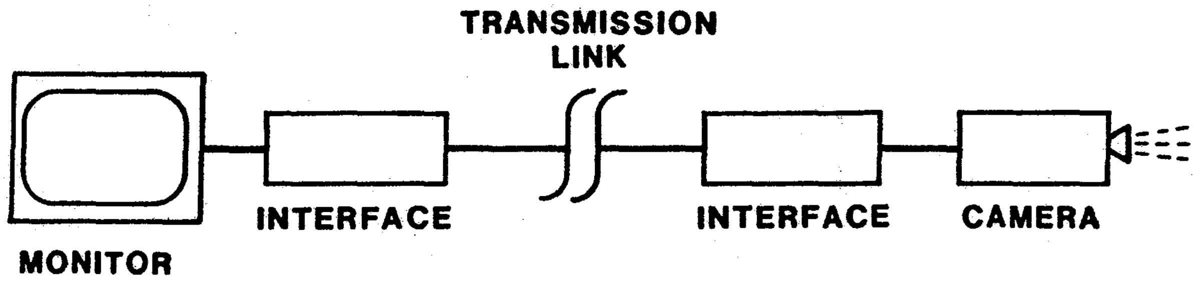


Figure 1 - Conventional Television System

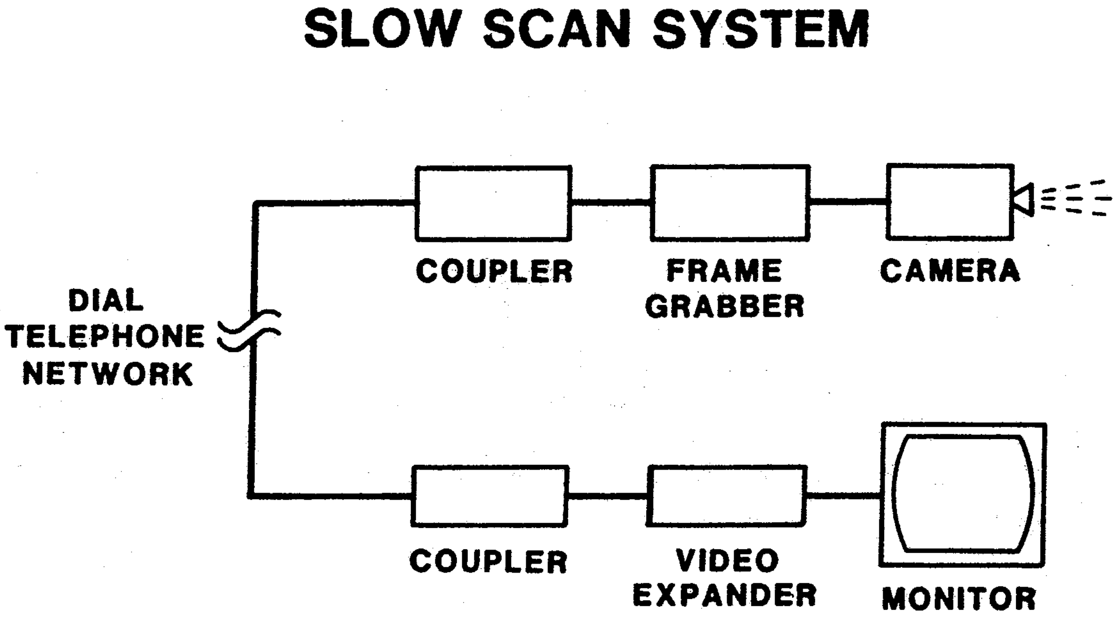


Figure 2 - Slow Scan Television System

1.2 Slow Scan System Overview

A simple, one-way slow scan system consists of the following elements:

TRANSMITTER

1. CCTV camera (for image pickup).
2. TV monitor (for assessment of picture produced by the TV camera; could be portable and would be used for testing and adjustment only).
3. Scan converter (for reduction of the signal from the TV camera to audio frequencies).
4. Modem (for converting the slow scan TV signal to a form suitable to the telephone line, typically an amplitude modulated or frequency modulated audio tone).
5. An interconnection to the dial-up phone system.

RECEIVER

6. Interconnection to the dial-up phone system.
7. Modem (for demodulation of the transmitted signal).
8. Scan converter with memory (for reconversion of the signal to normal TV rates).
9. TV monitor (for viewing of the reconstructed image).

Typically, modems are built into the scan converter electronics, thus simplifying system appearance. In essence, a "black box" connects the CCTV camera to the phone line at the transmitting end of the system and a second "black box" connects the phone line to TV monitor at the receiving end. The user no longer is able to view a rapidly changing picture as in the case of normal CCTV, but must wait 30 - 120 seconds before a complete picture will be reproduced at the receiving location.

Depending upon hardware configuration, the picture to be transmitted may or may not be "frozen". In some kinds of low-cost converters, it is necessary that a stationary image be provided from the TV camera in order to avoid geometric distortions in the reproduced picture. This is easily accomplished when looking at normal graphic material, but is a handicap when looking at traffic. A useful accessory to the transmitting terminal equpment is the "frame grabber" which allows a single image to be "frozen" before transmission.

Time is the essential factor in slow scan TV communications, and the amount of time required to transmit a single picture is primarily determined by two factors: bandwidth of the communications link, and resolution of the reproduced image. The dial-up phone network provides a basic limitation to bandwidth, and, although the useful frequency range of a dial-up circuit may be approximately 300 to 2500 Hertz, it is usually necessary to transmit a DC component in the slow scan TV signal. This is usually accomplished by amplitude or frequency modulation of an audio tone, with the result that the effective bandwidth of the transmitted data may only be on the order of one kilohertz, or about 2000 bits per second. Under those conditions, various image resolutions can be transmitted over the following time periods:

64 x 64 bit array = 2 seconds

128 x 128 " " = 8 "

256 x 256 " " = 32 "

256 x 512 " " = 64 "

512 p 512 " " = 128 "

512 x 1024 " " = 256 " .

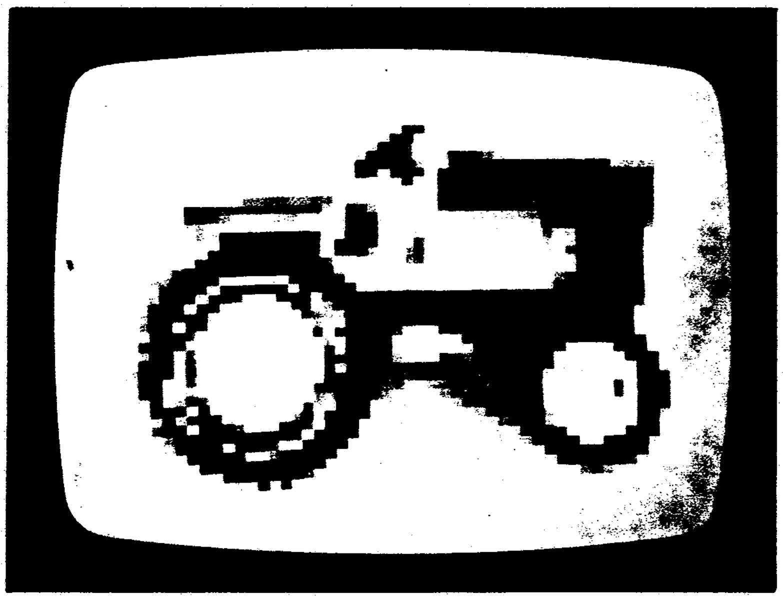
Figures 3, 4 and 5 show examples of picture coarseness. In general, 64 x 64 pictures are too coarse to be useful except for vehicle movement detection, while 256 x 256 or higher resolution provides useable imagery.

A typical slow scan system for monitoring traffic would require a camera atop a light standard, a control cabinet requiring power and telephone access, and a TV monitor at a remote location. Pan and tilt camera functions would be controllable from the remote location, as well, so that the camera could be positioned as needed. Such a system offers a desirable alternative for site monitoring of high density traffic areas, construction zones, and busway and other special lanes monitoring.

1.3 **Trade Journals**[1]

The worldwide sales of slow scan equipment are estimated to be only about $10,000,000. There are about 35 manufacturers, past and present, directly or indirectly involved in slow scan products.

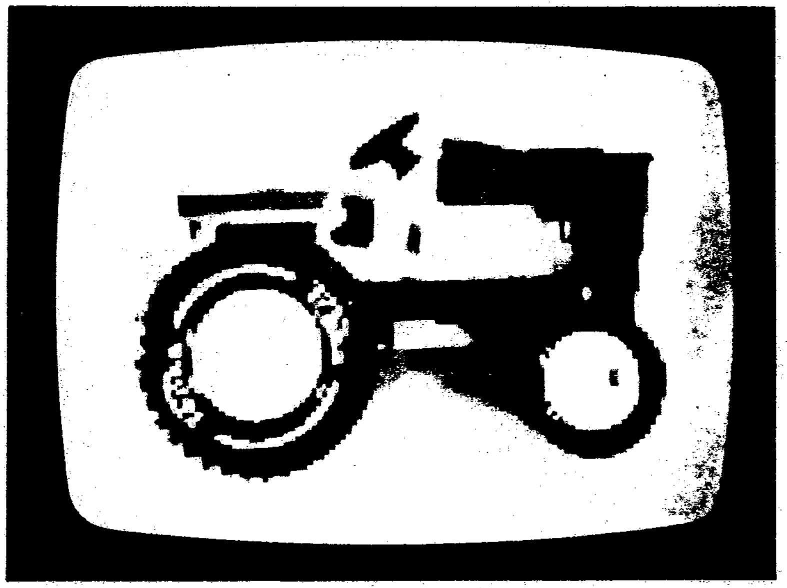
There is no trade publication devoted exclusively to slow scan television, primarily because it services a market that is too small to support the technical interest. In fact, there are few publications devoted to the technical end of television. The last effort was in the 1950's, and today's publications emphasize broadcasting and production. The closed circuit journals available focus primarily on applications, as well.



64 x 64 Picture Elements

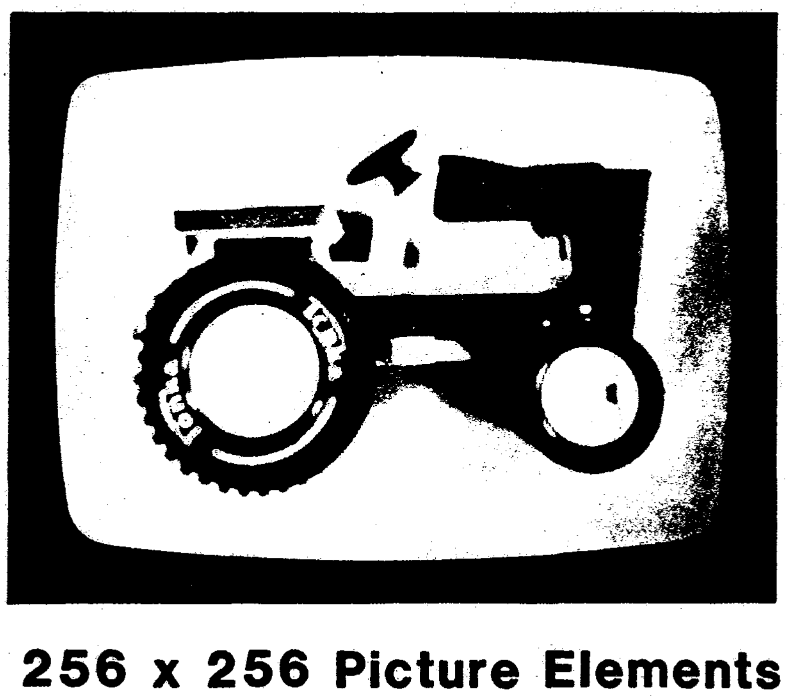
Source: Colorado Video

Figure 3 - 64 x 64 Picture Element Scene



Source: Colorado Video

Figure 4 - 128 x 128 Picture Element Scene



Source: Colorado Video

Figure 5 - 256 x 256 Picture Element Scene

1.4 High Bandwidth Links

The costs of installing a high bandwidth (microwave, fiber optics, or coaxial cable) data transmission link for real time transmission of video images are widely varying. Not only is the cost dependent on the area traversed, but also the equipment selected is a factor. Roughly speaking, prices in the range of $25,000 to $100,000 per mile, or higher, may be expected. In recent Texas projects, microwave usually has an initial appeal, until the licensing requirements are fully explored. Next, the use of the venerable coaxial cable is considered, and sometimes selected. Most recently, the cost of installing the cable so outweighs the cost of the cable and ancillary equipment, that fiber optics remains as the best choice for the transmission medium.

These high bandwidth links can only be justified in an ambitious traffic surveillance and control project, where the choice between field observers and remotely televised scenes must be made. Often, this is in conjunction with a comprehensive program of constructing new facilities. For lesser projects, where traffic surveillance is required, slow scan television is an alternative.

CHAPTER 2

COMPONENTS OF A SLOW SCAN SYSTEM

The basic components of a slow scan television system for traffic surveillance include the camera, control cabinet and associated equipment at the field site, and complementary equipment and television monitor at the office site.

2.1 **Cameras** [2,3,4]

A video camera is similar to any camera in that light reflected from an image is focused by a lens onto a plane inside the camera. Unlike the film camera, the video camera contains a camera tube which processes the image, and essentially performs the function of a television monitor in reverse. The evolution of video technology has provided the inexpensive and versatile vidicon tube, characterized by good light sensitivity, small size and excellent picture sharpness. Variations on the vidicon include the trivicon, an extremely low light level tube that uses silicon diodes and the newvicon, a sophisticated low light level tube produced by Panasonic. Another common camera tube is the Philip's plumbicon (lead oxide). Other high-performance broadcast quality color tubes are the chalnicon tube, a cadmium selenide design, or the saticon tube, a tin/oxide/selenium-arsenic/tellurium design.

The newest generation of pickup devices are not vacuum tubes at all, but large-scale integrated circuits that make use of a large number of microscopic "photo sites." Each photo site acts as the receiver of light energy. Resolution is determined by the number of photo sites on an area of the silicon substrate, or plate, which is similar in size to that of the normal scanned area of the pickup tubes mentioned previously. The benefit is that the lenses currently employed for those tubes may be used. Sensitivity of these charge-coupled device (CCD) image sensors is comparable with commonly used pickup tubes. Spectral response is also similar but with an extended range into the infrared region. Lag is practically nonexistent because charge transfer is almost instantaneous. Also very important is the resistance to damage by excessive illumination (such as inadvertedly pointing the camera to the sun), which results in little or no damage in the form of permanent image burn. These solid state cameras are preferable to tube type cameras for use in traffic surveillance.

2.2 **Zoom Lens**[2,5]

A motorized zoom lens is a necessity for detailing the traffic scene. This lens assembly has a continuously variable focal length, and utilizes both fixed and movable elements to permit the focal length to be varied. The term "zoom in" is used to indicate a closing down of coverage at the telephoto end, while "zoom out" refers to a transfer to a wide-angle coverage. Zoom lens are identified by their range of focal lengths. Hence, a lens with a range of 102mm to 17mm has 6:1 zoom range. Typical ranges are 3:1, 6:1, 10:1 and 14:1. Larger ranges are used in the very expensive lenses that are used in network sports coverage. A measure of the quality of the zoom lens is how well it remains in focus over the zoom range. With the substantial reduction in size of solid state cameras, it is not unusual for the motorized zoom assemble to exceed the size of the camera. A quality assembly will utilize shock mounted motors with slip-clutch protection and an adequate ground protection system to suppress RF noise generation.

2.3 **Lens Mount** [2]

In order for television camera manufacturers to offer their product for the widest possible application, the lens mounting system has been standardized. The most familiar lens mount is the so-called "C" mount, which uses a threaded cylinder about 25mm in diameter. This mounting system is handed down from 16mm film cameras and became standardized for CCTV cameras because of the wide variety of 16mm film-camera lenses that were available when CCTV cameras were introduced. Another lens mount that is more common in professional cameras is the bayonet mount. This lens uses index tabs that match recesses in the camera to mount and hold the lens upright. A locking ring secures the lens in place using a partial-turn action. Many cameras employ a combination-type lens mount that will accept both "C" and bayonet-type lens mounts.

2.4 **Camera Housing** [2,6]

A weatherproof camera housing is necessary to protect the camera and zoom lens assembly from exposure to the outdoor environment. Depending on geographic location and type of camera used, some additional accessories may be desirable, such as a heater, defroster, sunshield for protection from direct solar radiant heat, and blower for air circulation. A windshield wiper for the view window is also available. Construction material is typically steel or aluminum.

2.5 **Pan and Tilt** [5,6,7]

A motorized pan and tilt unit provides the mechanism for positioning the camera. A typical unit will swivel horizontally up to 360 degrees, and tilt plus or minus 90 degrees. The unit must be designed for outdoor operation, and the other primary requirement is that it be rated to handle the weight of the camera enclosure and its contents. Other features such as autoscan and variable speed drives are not particularly needed for traffic surveillance.

2.6 Control Cabinet

The control cabinet accommodates the power source entry, line termination equipment from the telephone company, power supply(s) for the camera and pan/tilt assembly, interface equipment for the pan/tilt drives, and the frame grabber/coupler for the capture, decomposition, and transmission of video images.

2.7 Pan and Tilt Receiver

The pan/tilt receiver accepts commands from the office location for positioning the camera. This unit may have a separate telephone line for its functions, share a telephone circuit with other units and respond only to a command coded for that location, or share the primary telephone circuit which is transmitting the slow scan image. In the latter case, the image can be transmitted or the camera can be moved, but not both at the same time. See the Pan and Tilt Transmitter section below for further discussion.

2.8 Slow Scan Transmitter

The slow scan transmitter is the component which makes the television surveillance system operate in slow scan mode rather than in real time. If the system were not slow scan, this component would be transmitting the TV image over a wideband medium such as optical fiber, coaxial cable or microwave. Instead, the relatively narrowband telephone line medium is used.

The frame grabber or freeze frame feature is required for a scene containing moving objects. At periodic intervals an image is captured and placed in a video memory. A representation of the components of this image, or picture elements, are transmitted one by one over the telephone line to a remote receiver. When all of the picture elements for an image have been transmitted, another image is captured, and the process is repeated.

For the traffic surveillance application, only one way transmission of image data is required. Fortunately, this allows the lower cost slow scan equipment to be utilized.

2.9 Slow Scan Receiver [8,9]

The slow scan receiver is located in the office environment, and is connected to the telephone line for its data input. Similar to the slow scan transmitter, this unit has a video memory. As picture element representations are received over the telephone line input, they replace the previous elements in memory to form a new image. The receiver has as its output the video signal from memory which drives a television monitor. Depending on whether the receiver can accommodate two full video images, the monitor may display a moving bar which represents the leading edge of updated information, or may display a static image until a complete new image has been received in the second memory.

2.10 **Television Monitor**

A standard television monitor is required.

2.11 **Pan and Tilt Transmitter** [5,7]

The pan and tilt transmitter enables the observer to point the camera to the area of interest. Usually, a manual control for the camera iris is also present. In a real time television system, any movement of the camera is instantly observed on the monitor, but not so for a slow scan system. In fact, major camera repositioning is exceptionally difficult in a slow scan system, and totally impractical in a traffic surveillance environment. It is necessary to have a system which implements commands to preset camera positions, and from these preset positions it is possible to make small positioning changes for special situations. In addition to pan and tilt prepositioning, the zoom and focus settings are also implemented for each position. Finally, an automatic iris adjustment feature is available to adjust for varying light conditions.

2.12 **Costs**

In 1980, the cost of equipment for a 4 camera slow scan system proposed by the City of Dallas was $81,625, exclusive of installation or the cost of developing plans and specifications. This is approximately $20,500 per camera location. Since traffic surveillance systems require operation in an outdoor environment, with the need for camera positioning by remote control, they are considerably more expensive than office-based systems. Further, this does not consider the cost of telephone lines or equipment maintenance, which can vary considerably with geographic location.

The 1985 prices are slightly higher, but minor differences occur in the example system. For a single camera site, the equipment price for a pilot project is calculated to be $26,700. A breakdown of the costs is shown in Figure 6. Each system under consideration will have its own factors influencing the cost, but conventional slow scan equipment costs are in the vicinity of $25,000 per camera.

The least expensive equipment for producing slow scan television would be that designed for non-freezing mode, e.g., still scenes. In the case of traffic surveillance, a meaningless, distorted view of moving vehicles would result.

FIELD SITE

CAMERA ASSEMBLY		
Camera	1,500	
Zoom Lens	300	
Pan/Tilt Unit	400	
Enclosure	300	
Mounting Brackets	100	
Subtotal	2,600	
CONTROL CABINET		
Transmitter	7,500	
Modem	2,500	
Camera Control Receiver	500	
Wiring	400	
Enclosure	300	
Subtotal	11,200	
INSTALLATION		
Camera	200	
Control Cabinet	400	
Electric Service	1,000	
Subtotal	1,600	
TOTAL FIELD SITE COST		**15,400**

OFFICE SITE

MODEM	2,500	
VIDEO EXPANDER	7,000	
MONITOR	700	
CAMERA CONTROL TRANSMITTER	600	
INSTALLATION	500	
TOTAL OFFICE SITE COST		**11,300**

TOTAL SYSTEM COST (SINGLE SITE)

FIELD	15,400
OFFICE	11,300
	$26,700

FIGURE 6 - Slow Scan System Costs

CHAPTER 3

ENHANCED SLOW SCAN

A conventional slow scan television system has application for traffic surveillance in specific cases. It functions as a time lapse sequence, with substantial loss of relevant events between scans. Slow scan television is impractical for meeting the demands of high volume urban freeway traffic studies, where locating and counting each vehicle is important. Ironically, this is the only environment that can justify the expense of television surveillance. Yet, some significant events have occurred over the past few years that have, or will have, a substantial impact on slow scan television. The result will be a dramatic shift toward the use of slow scan whenever bandwidth limited telemetry facilities are involved. This chapter will deal with some of the factors that influence this change.

3.1 Improving Slow Scan Performance

An improvement in slow scan performance is defined to be an increase in the scan rate in a manner which does not substantially degrade the usefulness of the image data. In short, this usually means there is a need for fast scan, rather than slow scan, surveillance. Real time television is 30 images per second. If the same quality of image could be achieved in 30 seconds with a slow scan system, it would be considered a very good slow scan system. Ordinarily, about 4.5 minutes would be required to transmit an image of 512 x 512 picture elements (this would be an image with the quality of normal black and white broadcast television). A fast scan system would be able to impart the meaningful image data in 1 to 5 seconds, but with some degradation of image quality.

There are several ways to improve the scan rate. The major ones are

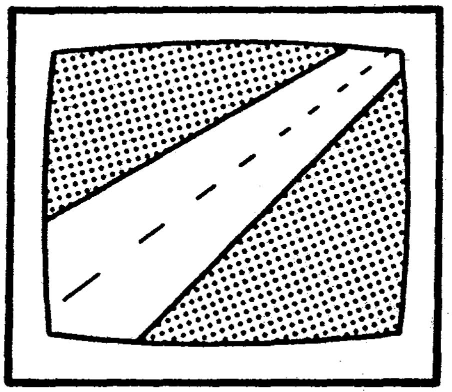
1. Transmit data at the highest possible data rate over the telephone line. Data rates of 4800 to 9600 bits per second are common over the dial up telephone network, but this is also a function of the quality of the telephone service provided by the local serving company. The higher the data rate, the more likely that data errors will occur. So long as synchronism can be retained, i.e., picture elements still appear at their proper place in the image, the random losses of data are integrated by the eye with practically no loss of usable information. Error rates that are intolerable for most data transmission are of far less concern for traffic scene images.

2. Use a conditioned line. A conditioned line, aside from its disadvantage of cost and sometimes, serviceability, is a straightforward way to achieve greater bandwidth. Tempered by practicality, the customer can essentially purchase as much bandwidth as needed from the telephone company. A conditioned line is a 24 hour, dedicated line. If the line goes out, then that specific line must be repaired, which sometimes can be a lengthy period.

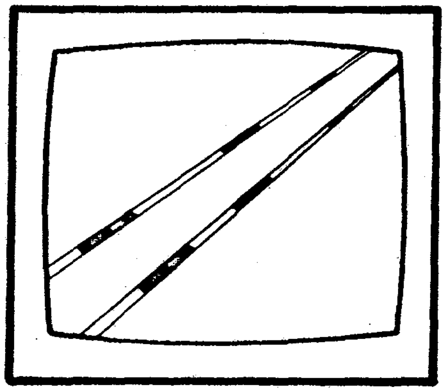
3. Send only the main area of interest in the image. Figure 7a depicts a roadway scene, but only about one half of the image is of concern to the observer. For any given traffic scene, much of the image is irrelevant, and usually 50% can be discarded, resulting in a twofold increase in scan images. Further, this process can be improved by the use of "lane strips" as shown in Figure 7b. This involves the data transmission of narrow strips of the image that occur in the center of the lanes. When visually monitoring for freeway incidents, for example, this technique is quite adequate for observing lane blockage. Other geometric patterns could be used for monitoring subsets of the image at high resolution and at correspondingly high scan rates.

4. Send only that portion of the image that has changed. Essentially, an image subtraction is performed as shown in Figure 8. To be absolutely precise, in traffic surveillance usually the only features of interest in the scene is the traffic itself, or the features which cause disruption of traffic. But traffic first must be observed to see if it is being disrupted, and during this phase only the vehicles themselves are of interest. If all of the background image was deleted except for the vehicles, then this would satisfy a major need of traffic surveillance. Unfortunately, this is more easily stated than achieved. First, a significant amount of computing resources must be available at the camera site to preprocess the image. Second, there is the problem of camera sway due to wind or vibration, and the image does not have a fixed frame of reference. This poses a considerable problem for reliably detecting movement in the scene, and falls well into the next generation of image processing algorithms.

5. Apply special encoding techniques to the image data. This procedure applies a set of processing algorithms to the image data prior to each time it is sent. The computer resources for this action are nontrivial, but well within contemporary microprocessors or multimicroprocessors. A number of preprocessing algorithms are available and a discussion of these will be covered in the sections below. Depending on the image data compression algorithm(s) used, the image may or may not be degraded.



7a. Roadway Scene With Background Removed



7b. Lane Strips Centered On Roadway

Figure 7 - Images Displaying Areas of Interest

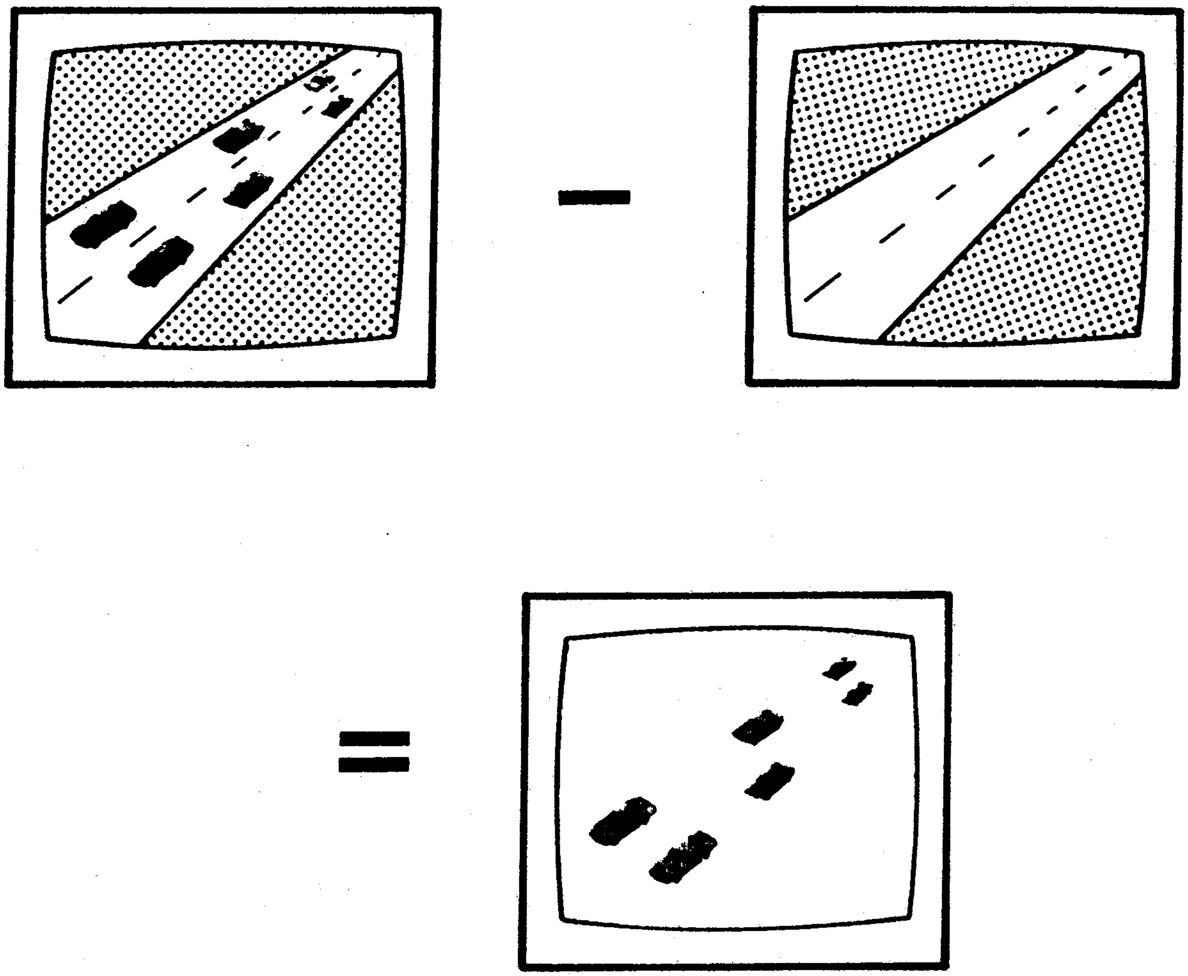


Figure 8 - Image Subtraction

3.2 Image Data Compression [10,11,12,13,14,15,16,17,18,19,20]

Image data compression is the reduction in the amount of signal space that must be allocated to a given data set. The signal space in this case is the time required to transmit the data set, which is also a function of the bandwidth required to transmit the given data set. In the case of slow scan, the bandwidth reduction has been made and is now some fixed quantity, such as 9,600 bits per second. The remaining option is to alter the data set (image), which is image data compression.

This data compression falls roughly into two categories, reversible and irreversible techniques. The literature has many names to describe techniques which fit these two categories, among these are noiseless coding to suggest a reversible technique and entrophy reduction to suggest an irreversible technique.

An entrophy reduction operation results in a reduction of information, since entrophy is defined as the average information. The information lost can never be recovered, so an entrophy reduction operation is irreversible. An example is the use of a threshold in monitoring sample values. If each picture element of an image is represented by 8 bits representing 256 shades of gray, then a threshold value of 128 could be used. A picture element with a value less than 128 could be represented by a "0", or otherwise by a "1", resulting in a compression ratio of 8:1. Another example of entrophy reduction is to average the value of groups of adjacent picture elements. If nonoverlapping aquares each containing 4 picture elements are averaged, then a compression ratio of 4:1 results. If the results are then reduced by a threshold, the a compression ratio of 32:1 can result.

Noiseless coding, on the other hand, is characterized by an examination of the statistical properties of the data prior to transmission. Suppose, for example, that the data set is sampled by groups of 3 bits, and it is found that the data is mostly zeros, and occurs in nicely decreasing probabilities as shown in Table 1. Then these 3-tuples can be assigned the codes shown in the right hand column of Table 1, resulting in a compression ratio of 1.5:1. At the receiving end, the coded bit string is decoded to exactly reproduce the original data. This technique, called differential chain encoding, is one of several noiseless coding techniques that can be utilized. The origin of the more sophisticated techniques of noiseless coding is with space probes which telemeter image data back to earth over limited bandwidth channels.

3-tuple	% Occurrence	Code
000	60	0
001	15	01
010	10	011
011	5	0111
100	4	01111
101	3	011111
110	2	0111111
111	1	01111111

Table 1 - Example of Noiseless Coding

3.3 Compressed Television Transmission (CTT) [21,22,23,24,25,26,27,28,29,30,31,32,33]

A recent demonstration of the use of data compression techniques in a traffic surveillance application is the Maryland Department of Transportation's pilot installation in Baltimore. Consisting of a single camera at the I70-I695 interchange in Baltimore, and a monitor at the MDOT offices in Glen Burnie (some 10 miles away), the system transmits compressed images over a 9600 baud, conditioned, leased telephone line. The project was initiated in 1981, and the results are available in the final report issued in late 1985. This report will not detail the many aspects of the Maryland project, but a brief summary follows as an introduction for the work done on this study.

The Maryland project was a joint effort between the Federal Highway Administration (FHWA), the Maryland Department of Transportation (MDOT), the Jet Propulsion Laboratory (JPL), and Dalmo Victor (DV). The primary objective was to demonstrate the use of image compression techniques in a traffic surveillance environment. The technology utilized was derived from techniques developed by the National Aeronautics and Space Administration (NASA) and JPL, for the unmanned space program to transmit TV images taken by spacecraft to Earth over limited bandwidth radio links. Under NASA's Technology Transfer Program, a joint effort between MDOT, FHWA, JPL and DV formed the demonstration project. JPL developed prototype hardware and software, and DV chose to participate as the commercial vendor in developing a product based on this technology. The project was funded by FHWA and MDOT supplied the site, design, specifications, and implementation details for the system. For a period of time, both the DV and JPL equipment was operational at the site. A demonstration of the working system was held in November, 1983, and the system continues to function with the JPL equipment to date. The 1983 demonstration showed the various image rates that can be achieved by varying the frame size (% of original picture) and compression ratio (which varies the quality of the image). The demonstration was successful and showed that such a system was feasible and capable of achieving the desired result. As is the case with many demonstration projects, the cost was substantial and tempered the interest of other agencies that might be interested in installing an enhanced slow-scan system. The various details of the system are chronicled in references listed at the beginning of this section.

One of the questions that arose about compressed television transmission (CTT), and which became one of the objectives of this study, was the image quality resulting from varying field conditions. The Maryland system had a very fine, rock-steady camera support, which presented an idealized situation. Typical camera mounts are more apt to be relatively flexible poles, such as light standards, which wave in the breeze. Other unknowns were the influence of varying light conditions and operation in the rain.

To test these variables, a number of traffic scenes were videotaped in Houston, Texas. Many variations in image quality were achieved by taping under the following conditions:

1. Taping at sunup, while vehicle lights were still on.

2. Taping during early morning fog.

3. Achieving a low camera angle by standing on the top of a truck at roadside.

4. Natural movements from unsteadiness of hand held camera.

5. Simulating wind buffeting of camera by rocking back and forth.

6. Panning the camera at high speed.

7. Varying the iris setting from closed to full open.

8. Taping high density traffic scenes from a bucket truck, with the boom overhanging the freeway.

9. Taping high density traffic scenes from a pedestrian overpass.

These videotapes were made with Sony portable videotape equipment, and recorded on Sony KCS 20 videocassettes (3/4" tape). Approximately 1 1/2 hours of scenes were taped.

An arrangement was made with Dalmo Victor in Belmont, California, to process these videotapes through their Vidcomp equipment, similar to that supplied for the Maryland demonstration project. Since their equipment would only process black and white images, it was necessary to first play back the source videotapes over a black and white monitor, and then use a black and white camera to monitor the screen's image, which was the image input to the Vidcomp equipment. This circuitous procedure resulted in little, if any, loss in picture quality.

The results were highly gratifying. In summary, the equipment reproduced compressed images at approximately two second intervals, simulating a 9600 baud channel. Various compression ratios were used, but in all cases the resulting compressed images were of very high quality and totally adequate for traffic surveillance. The output from the Vidcomp equipment was similarly recorded on a 3/4" video tape cassette, and was available for delayed study. Thus the final product was a black and white, degraded image, time lapse counterpart of the original videotape. It was felt that some problems might arise with the variations in field conditions that were encountered. This was not the case, and the image degradation was not a factor in observing traffic operations.

A varied assortment of compression ratios was used for the scene sequences. The audio channel of the videotape was used to announce the compression ratio at the beginning of each of 97 sequences. The compression ratio is the ratio of the number of bytes in an uncompressed image (256 x 256 = 65536) to the number of bytes transmitted after compression. The distribution of compression ratios tested is shown in Table 2. A series of comparison photographs is shown in the Appendix. Each photograph shows the original videotaped image on the left, and the Vidcomp image on the right. In general, there is very little image degradation after the compression/decompression operations. The Vidcomp frames were displayed at 2-5 second intervals, depending on the compression ratio currently in use. To obtain these photographs, two video playback units were connected to side-by-side monitors. The playback units were then synchronized and the monitors photographed while the Vidcomp image on the right was static. The image on the left continued to change, which accounts for the slight discrepancy between vehicle locations in the two scenes.

The original cost of a Vidcomp transceiver (2 required to complete the link) was $75,000, or a total of $150,000. The camera is the input to the field unit, and the TV monitor is the output from the office unit. A substantial, introductory price reduction to $38,500 per transceiver has been mentioned by Dalmo Victor.

Compression Ratio	Bytes Transmitted	Occurrences
3:1	21K	32
4:1	15K	5
6:1	10K	3
7:1	9K	1
8:1	8K	12
9:1	7K	6
10:1	6K	10
12:1	5K	13
16:1	4K	9
20:1	3K	5

Table 2 - Frequency of Test Tape Compression Ratio Sequences

CHAPTER 4

ALTERNATIVE SYSTEM FOR TRAFFIC SURVEILLANCE

For any given application which uses hardware, it is nearly always possible to tailor a system for specific needs. The benefits are not always in line with the costs, however, and it is usually simpler and less expensive to go with off-the-shelf equipment. The pervasiveness of the computer has dramatically improved the possibility of tailoring systems through software. Traffic surveillance is no exception. In a situation where limited bandwidth is a given constraint, it is still necessary to have a camera and a monitor. The issues remaining are to have 1) a device which accepts input from the camera and transmits data over a telephone line, and 2) a device to receive data over a telephone line and produce output for a television monitor. This chapter deals with an alternative which falls within this framework.

4.1 Overall System

A system utilizing general purpose microcomputers at each end is proposed. At the field site, a microcomputer with an image digitizer and modem is utilized. At the office site, a microcomputer with a display driver, modem, and CRT with light pen input is utilized. This system configuration is shown in Figure 9. The office computer can have multiple modems and display drivers as a function of how many independent image data streams it can accommodate. Microcomputers in the personal computer class are utilized. Specific brands cited in the following sections are illustrative, and may have substitutions which meet or exceed compatibility requirements, availability of peripherals, and performance requirements.

4.2 Field Configuration [34,35]

The field configuration consisting of microcomputer, modem and digitizer has the equipment costs shown in Figure 10. The camera cost is not included since it would be required with any technique. As with any electronic equipment, these components would require a weatherproof cabinet.

4.3 Office Configuration [34,36,37]

The office configuration consisting of microcomputer, modem and display driver has the equipment costs shown in Figure 11. The TV monitor is not included since it would also be required with any technique.

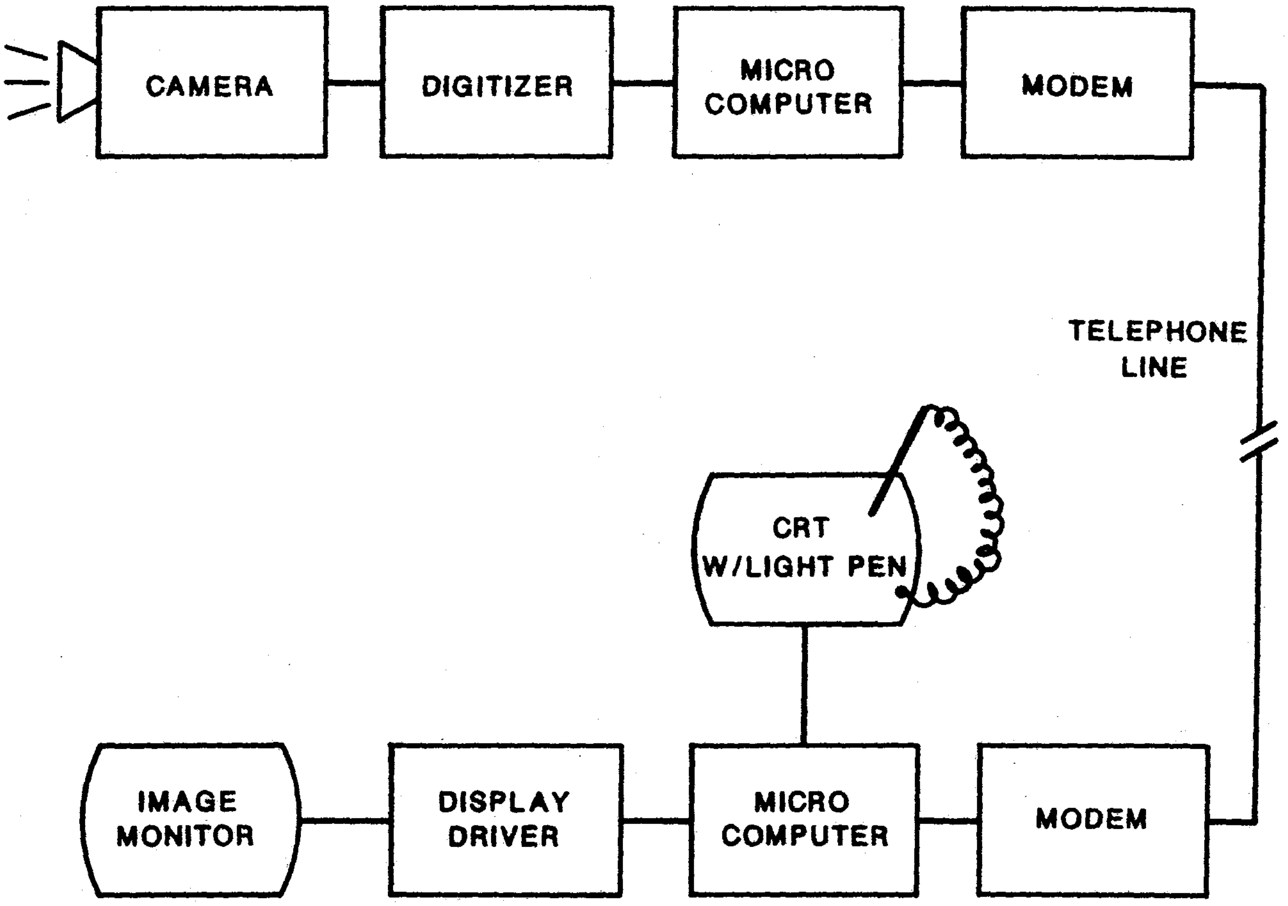


Figure 9 - Microcomputer-Based Fast Scan System for Traffic Surveillance

IBM Portable PC with 256K RAM, one 360K disk, and display	3,000
DCA/Telebit 10,000 BPS modem	2,000
Oculus-100 Binary Frame Grabber	1,000
	$6,000

Note: Camera price not included since it would be required with any technique.

Figure 10 - Microcomputer-Based Field Transmitter

IBM PC with 512K RAM, one 360K disk, and display	3,000
DCA/Telebit 10,000 BPS modem	2,000
CSD Ultra-Res monochrome graphics system with light pen input	1,000
	$6,000

Note: TV monitor cost not included since it would be required with any technique

Figure 11 - Microcomputer-Based Office Receiver

4.4 Software

Software cost is not quoted since it has a widely varying range depending on programmer, and utilization. If this system were programmed and utilized for only one camera and monitor, it would be costly. For more cameras, or more systems, the software cost approaches a figure less than any major component in the field/office configuration. For a definite range for single copy to multiple, amortized copies, the figures would be approximately $50,000 to $1,000.

4.5 System Operation

The system, utilizing a full duplex communication feature, would operate in a particular mode until instructed to do otherwise. The light pen feature allows the specification of areas of interest on a background of the full image. Frequently, the four vertices of a trapezoid would suffice for delineating an area of interest such as the roadway image. The "lane strips" mentioned earlier could be defined by two points per lane (top and bottom) with keyboard or menu selection of strip width. Similarly, by keyboard or menu selection, the operator could select options for reversible and irreversible image processing, as well as for camera positioning.

CHAPTER 5

FACTORS INFLUENCING THE FUTURE OF SLOW SCAN

In the past two years, there has been a substantial increase in the number of products introduced that deal with image processing and transmission. While sometimes unrelated, these disparate items are forming a fragmented picture of the future of slow scan television. These developments are certain to bring cost benefits to the use of slow scan in traffic surveillance.

5.1 Teleconferencing [38,39,40,41,42,43,44,45,46,47,48,49,50,51,52]

The big market for slow scan television at this time is in the field of teleconferencing, the theory being that any picture is better than no picture at all. Some interactive systems have evolved, where an image can be annotated by the participants. So, even when a person is not in view, the material being discussed can be viewed. Teleconferencing centers have been established, where participants gather and communicate with a distant teleconferencing center. While this suggests an array of cameras, monitors and interactive sketching devices, the centers may be linked with higher bandwidth communication channels, as well. This commercial area is slow-scan oriented at this time, and complements the "telecommunications in place of travel" theme embraced by some transportation researchers for many years.

5.2 Picture Phones [53,54,55,56,57,58,59,60]

The picture phone concept has been resurrected. If not a real time picture, at least some snapshots can be transmitted with the slow scan technique. The various companies involved in this area are targeting the equipment for business use, typically for transmission of drawings and allied media. Such a work station generally has a camera, display and light pen.

5.3 Cellular Telephones [61,62,63]

Cellular telephones have gained widespread acceptance in major metropolitan areas, and data transmission rates of 300 to 2400 bits per second have been tested. It is inevitable that innovative applications for mobile data transmission will evolve around these devices. The bandwidth constraint as always will encourage slow scan techniques for image transmission.

5.4 Satellite Communication [64,65]

As always, the slow scan communications channel is not limited to telephone lines. The need to link computer terminals at remote sites to central offices has led a company to develop a 2 foot diameter antenna for an earth station to receive satellite signals with no interference. This was for one way transmission, and now a station with a parabolic antenna size of 72 x 48 inches permits 2 way data transmission. The interface is an RS-232 port with bit rates from 75 to 19,200 bits per second. This technology offers strong possibilities for traffic surveillance, as well as control.

5.5 **High Speed Dial Up Lines** [66,67,68]

The prospect of ordinary telephones allowing data transmission rates greather than 9600 baud would be an advantage for slow scan television. AT&T has announced that Illinois Bell is testing circuitry that will allow ordinary telephone lines to transmit data at a rate of 56,000 baud. This would permit the transmission of uncompressed 256 x 256 bit images in 11.7 seconds. With compression techniques, the image could approach real time. Meanwhile, Bell Atlantic has demonstrated an Integrated Services Digital Network (ISDN) through the public switched telephone network. Through its central offices in Washington, the company showed that it could transmit voice, data, and video images simultaneously over existing phone lines.

5.6 **Optical Data Transmission** [69,70,71,72,73]

Infrared and laser communication devices are useful for short range, line of sight data links up to 9600 baud. In a slow scan system, such a link offers an advantage when the camera site cannot be easily served with a telephone line, or even has to be powered by batteries. For temporary setups, such a link can be an advantage, providing the means to get the signal to a site where power and telephone is available. Ranges up to 10 miles are claimed, but one mile is more realistic for varying atmospheric conditions.

5.7 **Radio Data Transmission** [74,75,76,77,78,79]

Data transmission by radio always seems to be mentioned as a possibility but never seems to attract a wide following. Interconnection of traffic signals by radio would seem to be one of the best applications of this technology, and although equipment is available for this purpose, it has limited acceptance.

A good working example of slow scan tranmission over radio is a test system utilized on an AIRTRANS vehicle at the Dallas/Fort Worth airport. This system permits on-board vehicular surveillance by means of a closed-circuit TV camera working with an FM two-way radio. Using a 3K Hz channel, 64 x 64 pixel scenes are transmitted in 0.75 second, 128 x 128 in 3 seconds, and 256 x 256 in 12 seconds.

For the situation again where it is inconvenient to have a telephone line at the camera site, a unique device is available to transmit images at normal TV broadcast frequency. Strictly speaking, it is a low power television transmitter in an attache case, but it fits better in the radio category since it has a maximum range of 100 feet. Any TV set in that range, tuned to UHF channel 14 will receive the signal.

A very recent product announcement is the wireless modem. This is a FM transceiver operating at about 72 megahertz, with a data rate of 2,400 bps. While this data rate is almost too slow, even for slow scan TV, it may have isolated application for image transmission. Utilizing a Z-80 microprocessor and packet transmission techniques, it is a sophisticated device with sufficient intelligence to overcome many of the obvious objectives to data transmission by radio.

5.8 Consumer Electronics

The real advances benefitting slow scan television will occur in the consumer electronics arena. The next generation of personal computers will require some very powerful hardware features in order to survive in the marketplace. These will be based on 32 bit microprocessors, with graphics features driven by the newly emerging image processing and signal processing chips. The new Commodore Amiga, for example, has a frame grabber option. With these features, some of the more sophisticated image compression techniques can be applied routinely, and fast scan results can be expected. In short, the hackers will introduce the techniques and general use will quickly spread. All this will be to the benefit of traffic surveillance.

In a similar vein, much of the early use of slow scan was by ham radio operators, and the radio transmission of still pictures of operators and equipment was (and still is) widespread. Confined to this special interest group, the application was not not generally known. The next popular wave of slow scan application will be among the special interest group that has access to a personal computer, which will, for all practical purposes, make it a household convenience.

CHAPTER 6

CONCLUSIONS

6.1 Findings and Conclusions

A substantial body of literature was reviewed; a large portion of the writings in this area have originated in the amateur radio field. Approximately 160 references were located, and of these, 30 were obtained for review as applicable to traffic operations. Major application areas for slow scan television include business (teleconferencing), medicine (X-ray transmission), and space probes (planetary images).

Equipment literature was acquired from the several leading manufacturers of slow scan equipment. The equipment available for a traffic operation monitoring system is relatively low cost: $25,000 to $30,000 installed, per camera site. The total worldwide annual sales of slow scan TV equipment is about $10 million; therefore, the number of equipment manufacturers is limited, and are primarily in the U. S. and Great Britain.

Study findings indicate that more choices are available for slow scan equipment configurations and techniques than traditionally advertised. Some of the are: Compressed Television Transmission (CTT). The video data is examined for patterns of information prior to transmission. The patterns are encoded and the result is a significant decrease in the amount of data to be transmitted. Picture Masking. Seldom does the entire field of view of the TV camera need to be transmitted. Reasonably priced equipment is available for personal computers (PC's) to digitize video images. With a small amount of preprocessing, the PC can transmit selected portions of an image over the telephone line to a similarly equipped PC for viewing. Digital Radio Transmission. Radio transmission of slow scan data is feasible by radio, though at a somewhat slower rate than by wire. Commercial service is available for data communications via traditional FM 2-way radio systems. High Speed Telephone Link. AT&T is installing equipment to provide high speed, dial up data communication service for most major U. S. cities by the end of 1986. This will change today's concept of slow scan TV to fast scan TV, allowing good resolution images to be transmitted once per second. FM Subcarrier Transmission. A recent ruling by the FCC allows commercial FM stations to offer additional services on radio frequencies near the primary transmitting frequency assigned to the station. This channel space can be used to transmit slow scan data, as well as serve other data communication needs. Demand Scanning. This technique compares the new image to the one previously transmitted, and only sends that portion of the new image which has changed.

Of the techniques mentioned, CTT is a sophisticated technique for transmitting image data over a limited bandwidth channel. The technique was used in spacecraft probes by NASA, and is being applied to new areas through the Jet Propulsion Laboratory's (JPL) technology transfer program. The basic problem is one in which discrete data sources (the traffic scene image) are to be coded into binary representations from which the original can be retrieved precisely. Thus these binary mappings are reversible. The statistical characteristics of the traffic scene are such that certain things happen more often than others. It is possible to reduce the average number of bits required by representing the frequently occurring cases with fewer bits than the infrequent ones. A set of practical techniques was developed some time ago for the specific task of providing efficient coding of spacecraft imaging data where exact reproduction was a requirement. Using these algorithms as building blocks, the CTT techniques are effective in an imaging data compression system.

A CTT system was installed in Baltimore, Maryland, using separate equipment designed by JPL and Dalmo Victor. Both systems performed adequately, with the Dalmo Victor version more expensive, but with a greater number of features. A conventional slow-scan television system would take 68 seconds to transmit a 256 x 256 8-bit picture over a 9600 bit per second channel. The CTT technique will send the same pictures over the channel in about 7 seconds using a compression factor of 8.

As a further test of the CTT system, traffic scenes were videotaped in Houston for playback through the CTT equipment at the Dalmo Victor plant in Belmont, California. These scenes represented a controlled experiment to observe effects of camera shake, different light intensities, and image composition. In all cases the equipment performed satisfactorily.

The significant study finding was that a standard microcomputer system with digitizer and high speed modem, programmed specifically for traffic surveillance needs, has been found to offer a significant advantage over conventional slow scan equipment and the fast scan equipment offered by the CTT technique. Also, significantly lower costs would be realized, after the initial software development phase. This basic system consists of a camera, microcomputer, modem and digitizer at the remote location. At the central site, the equipment consists of a microcomputer, modem, display driver, and TV monitor. Two way data transmission would occur from office to field to command data aggregation and subsetting, and reverse transmission of the image according to command. By sending only specific segments of the image, image update periods of 1 to 5 seconds should be possible.

Consumer electronics will have a strong influence in bringing down the costs of future systems. Image data processing chips are now becoming available, as well as signal processing chips. The coming generation of home computers will have image digitizers. Digital television sets are now available, using an early generation of signal processing chips. These two areas will provide substantial benefit for future systems of television traffic surveillance.

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Mausui, Kazuyuki (Hitachi Ltd, Tokyo, Japan), Achiha, Masahiko, Fukinuki, Takahiko, IEEE Transactions Communications vol. COM-29, No. 12, December 1981, p. 1977-1981. **HIGH-SPEED TRANSMISSION OF SEQUENTIAL FREEZE-PICTURES BY EXTRACTING CHANGED AREAS.**

A very high-speed freeze-picture transmission system using telephone lines is realized by sending only the changed areas from the previous picture. The new system is much simpler than interframe codecs because it does not employ complicated coding mode controls, addressing, or buffering. Block size of the changed areas is selected to satisfy both fast transmission speed and circuit quality is achieved by extraction of changed blocks using both the average value of the picture signal difference in each block and the maximum value. Protection of picture data against transmission errors is achieved using two synchronizing data groups among tripled addressing data groups. Reduction of impairments due to errors in DPCM picture data using backward decoding is proposed.

Brown, Daniel P. (Motorola Inc., Schrumburg, Illinois), IEEE Transactions Consumer Electronics, vol. CE-26, No. 3, August 1980, Chicago Spring Conference, Chicago, Illinois, June 18-19, 1980, p. 247-250. **VIDEO SURVEILLANCE SYSTEM FOR PUBLIC TRANSPORTATION VEHICLES USING 2-WAY LAND-MOBILE RADIO.**

A system has been developed to permit on-board vehicular surveillance by means of a closed-circuit TV camera working with an FM two-way radio. This system was installed on a AIRTRANS vehicle at the Dallas/Ft. Worth airport in the fall of 1979. A snapshot is derived from the closed-circuit camera, to be transmitted in 3 seconds over a standard business or public safety channel. The pictures are composed of 16,384 picture elements (pixels), arranged as 128 lines, with 128 elements per line. The desirability of video surveillance is discussed, along with recent trends in electronics and communications that have helped make it practical. An examination is made into the general problem of sending visual information over narrowband FM radio, followed by a closer look at the specific bandwidth/resolution/time tradeoffs that were made in the AIRTRANS system.

Smith, B. A., **A DIGITAL SLOW TO FAST SSTV CONVERTER FOR MONOCHROME OR COLOUR,** Radio Communications (Great Britain), vol. 59, no. 3, p. 221-225, 1983.

Construction details and calibration procedures are outlined for this slow-scan converter.

Mirabito, M. M., **TELEVISION SYSTEMS AND SLOW-SCAN VIDICONS ON NASA SPACE PROBES**, SMPTE Journal, vol. 91, no. 6, p 542-546, 1982.

The television camera was and still remains one of NASA's scientific tools for the exploration of outer space. Unmanned probes have penetrated space to examine the Moon, Mercury, Venus, Mars, Jupiter, and Saturn. As components of their packages, the Ranger, Surveyor, Mariner, Mars Orbiter, and Voyager probes incorporated television subsystems with slow-scan vidicons as their imaging sensors to photograph these bodies. This paper examines the use of slow-scan vidicons and their television cameras on NASA's unmanned space probes in the exploration of our solar system.

Mannix, D., **SLOW-SCAN TELEVISION IN INDUSTRIAL AND BUSINESS APPLICATIONS**, Middle East Electronics (Great Britain), p. 27-29, 1982.

Describes phone line television (P. L. TV) equipment that works with standard voice grade lines by converting the television video signal (3.5 MHz) to audio, which the phone system is designed to handle. It does this by freezing a single picture in an electronic memory and transmitting it over, say, an 8.5 second period. The picture is then gradually reassembled, at the receiving end, into a similar memory and rapidly replayed into the CCTV display (monitor). The main commercial application is in the security field where it is used for television surveillance and alarm verification. It has also been used as a supplement to teleconferencing.

Ingram, D., **AMATEUR RADIO FRONTIERS. II. SLOW SCAN TELEVISION**, CQ Radio Amateur Journal, vol. 37, no. 8, p. 17-19, 1981.

One of the most popular and exciting frontiers in amateur radio today is the visual communications world of slow scan television. Transgressing a step beyond conventional amateur radio activities, SSTV is a narrow bandwidth video system which can be used in the advanced class portions of 80, 40, 20, and 15 meters, and in the complete S.S.B. portion of 10 meters.

Ruh, H., **AN INTRODUCTION TO SLOW SCAN TELEVISION**, CQ Amateur Radio Journal, vol. 35, no. 6, p. 28-33, 1979.

The author explains the principles of SSTV, the equipment needed, and the methods by which the amateur can operate.

Sorge, G., **TELEVISION (SSTV) - IN CHEQUE CLEARING SYSTEM APPLICATIONS**, Autophon Bulletin (Switzerland), no. 19, p 14-16.

Using the SSTV system described, cheque transactions can be handled via a 2-wire subscriber line over a distance of up to 6 km. without amplification. Some typical applications of the SSTV system in conjunction with cheque facsimile transmission systems are described.

Burnett, P., **THE ROBOT MODEL 400 SLOW-SCAN TELEVISION SCAN CONVERTER**, Radio Communications (Great Britain), vol.54, no. 3, p.212-214, 1978.

Apart from the power supply, front and rear panel controls and sockets, all circuitry is located on one plug-in double-sided glass-fibre pcb. The usual video source inputs (tape, radio, camera and auxilliary) are provided, and a most useful built-in grey-scale generator is also available. The 400 performs the scan conversion in both directions: i.e., SSTV out from a fast-scan camera, video tape-recorder or the demodulator stages of a TV receiver and it will display received SSTV pictures on a fast-scan monitor or domestic TV receiver from a radio or audio tape-recorder source.

Dewitt, B., **SLOW SCAN TELEVISION, OVERVIEW '77, PART I**, CQ Radio Amateur Journal, vol. 33, no. 1, p. 17-18, 1977.

Describes slow scan TV principles and terminology.

Dewitt, B., **SLOW SCAN TELEVISION, OVERVIEW '77, PART III**, CQ Radio Amateur Journal, vol. 33, no. 4, p. 42-45, 1977.

For Part II, see vol. 33, no. 2, p. 57 (1977). Discusses the operational aspects of slow scan TV for amateur radio.

Southworth, Glen R., **A HIGH-DEFINITION STILL-FRAME TELEVISION SYSTEM**, SMPTE Journal, vol. 92, no. 8, p. 834-842, 1983.

Television systems with 1000 lines or greater resolution have been available for several decades, but the relatively wide bandwidths required have precluded their use except for short distances. One solution is the generation of narrow bandwidth, single frame video signals for transmission purposes, with scan conversion by means of digital memory at the receiver. The system described in this article incorporates two methods for transmission of high-resolution "slow-scan" TV signals: the first using a conventional 1000&CCT camera in conjunction with an unusual sampling/digitizing scan converter; and the second consisting of a solid state linear array with 35-mm optics and horizontal axis scanning produced by a rotating mirror. The receiving part of the system consists of analog signal processing, digitizing, and addressing of a memory by which the signal is converted to an analog video signal, with the resultant image on a standard TV monitor.

Balasubramonian, K., Nithiyanandam, N., Rajappan, K. P., **OPTICAL SECTIONAL MEANS OF IMAGE PICKUP AND VOLUMETRIC DISPLAY: SOME METHODS OF REALIZATION OF 3-D TV**, Journal Optical (India), vol. 12, no. 1, p. 19-23, 1983.

Two methods of realization of a 3-D TV based on optical sectional means of imaging are described. The first method is the modified version of the recently proposed volumetric 3-D TV which is well suited for real-time consumer television and the second method is ideally suited for slow scan large screen 3-D TV.

Hameenaho, V., **A DIGITAL VIDEO STILL PICTURE TRANSMISSION SYSTEM USING NARROWBAND VOICE CHANNELS**, Saehkoe Electrical and Electronics (Finland), vol. 56, no. 6, p. 10-13, 1983.

Transmission of pictorial ifformation over narrowband channels like telephone networks is a growing practice in a wide and versatile application area. Solutions to compromise between the cost, the performance, and the image quality have been introduced. Two concepts can be distinguished: facsimile and narrowband television.

Foot, N., **GETTING INTO SSTV: JAOBZC/ZL 1LH CONVERTER**, Practical Wireless (Great Britain), vol. 59, no. 6, pp. 56-58, 1983.

A review of a low cost self-build SSTV receive converter. With the increase in SSTV activity over the last few years, particularly on the HF bands, brought about by the availability of digital scan converters (over 14,000 stations worldwide are estimated to have SSTV capability), the author started looking for suitable constructional designs for a receive unit. Traditional circuits to be found in the current RSGB handbooks using long persistence CRTs were dismissed as being outdated, so a suitable design for a digital slow-to-fast scan converter was sought after.

Kenyon, N. D., **PRIVATE TV BY PUBLIC TELEPHONE**, Indian and Eastern Engineering, vol. 124, no. 12, pp. 538-541, 1982.

Conventional television signals are very expensive to transmit over landlines, because the signal occupies such a large part of the electromagentic spectrum that costly circuits and cables have to be used. British Telcom, the telecommunications part of the British Post Office, has developed a cheaper, digital slow-scan television system which uses the two-wire domestic telephone line and it is now being tried out in many different applications. For example, TV conferences can be set up, and distant radar displays are being made available at a port control office, using existing lines.

Spurdon, S., **ELECTRONIC SYSTEMS FOR SAFETY AND SECURITY**, Middle East Electronics (Great Britain), vol. 6, no. 2, pp. 23-25, 1983.

An overview of electronic surveillance, access control, intruder detection and alarm systems is presented. Particular reference is made to closed circuit television and the impact of the introduction of colour and slow-scan television. Various intruder detectors such as passive infrared, ultrasonic and radio alarms are described. The development of advanced microprocessor controlled digital communications which provide round-the-clock alarm monitoring of a whole range of alarms is discussed. The relative merits of ionisation of photoelectric domestic fire detectors are considered. Finally, the introduction of voice recognition systems in the field of access control and the role of computer software in the future are discussed.

Boyes, E. D., Muggridge, B. J., Goringe, E. J., Hutchison, J. L., Catlow, G., **IMAGE ANALYSIS AND PROCESSING FOR VERY HIGH RESOLUTION ELECTRON MICROSCOPY,** Electron Microscopy and Analysis, 1981, Proceedings of the Institute of Physics Electron Microscopy and Analysis Group Conference, Cambridge, England, pp. 119-122, September 1981.

Describes the coupling of a microconsultants Intellect 200 image analysis system based on a double 512*512*8-bit digital video framestore, to the first ultra high resolution version of the JEOL 200CX electron microscope which has a ctf d/sub 1/ of 0 25 nm and cut-off at less than 0 17 nm. A related system has been used to convert slow scan sem signals to television experiments off-line, whilst Hashimoto has described a simple 64*64 point system and Herrmann, et al, a more sophisticated one, both of which are quite slow in operation. Speed is important since to be used interactively the image acquisition and analysis together with any corrective action found to be necessary must all be accomplished within a realistic estimate of the natural stability of the microscope, which is typically of the order of one minute.

Axson, M. J., **INTRODUCING SSTV, PART** I, Practical Wireless (Great Britain), vol. 57, no. 8, pp. 41-43, 1981.

Outlines slow scan television systems which can be used on the HF and VHF amateur radio bands.

Axson, M. J., **INTRODUCTING SSTV, PART** II, Practical Wireless (Great Britain), vol. 57, no. 9, pp. 20-21, 1981.

Presents an examination of scan conversion techniques.

Kues, J. R., Benenfeld, A. R., Kazlauskas, E. J., **PROVIDING INFORMATION TO HEALTH-CARE PROFESSIONALS VIA TELECOMMUNICATIONS: A CASE STUDY,** Communicating Information: Proceedings of the 43rd ASIS Annual Meeting, vol. 17, 1980, Anaheim, California.

The telecommunications information network provides an information link between the University of Cincinatti medical center and health-care providers at four rural and semi-rural hospitals in southwest Ohio. Telephone requests for medical information are researched by the staffs of the health sciences library and the drug and poison information center. Requested information is conveyed to health-care providers via telephone and/or slow-scan television. Requests for information have been received from a variety of health-care professionals, including physicians, nurses, pharmacists, administrators, librarians, social service personnel and patients. Approximately one-third of the requested information is used for patient treatment. Personal knowledge, teaching and research are the other principal uses of information. These findings illustrate the extensiveness of the information needs in rural health settings afd the role telecommunications can play in meeting these needs.

Allnatt, J. W., Nicol, R. C., White, T. A., and Corbett, J. M., **PICTURE MODE FOR PRESTEL**, International Broadcast Engineering (Great Britain), vol. 11, nl. 174, pp. 20-23, 1980.

British Telecom Research Laboratories have for many years been carrying out both basic research and advanced development of picture coding techniques for the digital transmission of television pictures. To date this work has resulted in the construction of experimental codecs for the transmission of broadcast television pictures at 70 mbit/s, teleconferencing television at 2 and 8 mbit/s and slow scan television at rates ranging from 4.8 to 64 kbit/s. One recent application of these techniques has been to Viewdata systems, resulting in the unveiling at 'Viewdata 80' of the world's first picture Viewdata system, 'Picture Prestel'. This provides still colour television pictures of normal definition and gradation as part of a Viewdata page.

Rappaport, W., Skinner, F. L., Gitlin, J. N., Gayler, B., and Dunn, R., **A MICROPROCESSOR-BASED TELERADIOLOGY SYSTEM**, Proceedings of the Third Annual Symposium on Computer Application in Medical Care, Washington, D. C., pp. 441-444, October 1979.

Describes the background, purpose and design factors associated with a prototype, microprocessor-based slow-scan television (SSTV) system being developed to support the remote interpretation of radiographs. The development project began when a laboratory evaluation of an off-the-shelf SSTV system in early 1979 revealed that a higher- or variable-resolution capability was required for general radiology.

Gayler, B., Gitlin, J. N., Rappaport, W. H., and Skinner, F. L., **A LABORATORY EVALUATION OF TELERADIOLOGY**, Proceedings of the Sixth Conference on Computer Applications in Radiology and Computer/Aided Analysis of Radiological Images, Newport Beach, California, pp. 26-31, June 1979.

Increasing national attention is being focused on the feasibility of using slow-scan television (SSTV) for transmitting x-ray images over telephone lines from medically underserved areas to radiologist located in urban medical centers. The authors describe the results of an experiment conducted to determine whether an SSTV system currently being used in several rural communities is appropriate for general radiology at the primary care level, or whether changes in design features or image quality should be considered for future applications.

Barker, P., **AMATEUR SSTV**, Practical Wireless (Great Britain), vol. 54, no. 6, 1978.

Slow-scan television is introduced as a method of transmitting video information within the bandwidth of a normal single sideband signal.

Allenden, M., **OSCILLOSCOPE VIEWING HOODS**, Practical Wireless (Great Britain), vol. 53, no. 10, pp. 760-761, 1978.

The need for a cathode ray tube viewing hood became apparent when studying slow-scan television and the problem of daylight observation was encountered. The hoods shown were all constructed from black plastic plant pots, which are available in a variety of sizes, both circular and rectangular.

Tyce, R. C., and Boegeman, E. E., **INTEGRATING OPTICS AND SONAR FOR A DEEPLY TOWED VEHICLE**, Oceans '77 Conference Record, II, Los Angeles, California, 1977.

Geophysical surveys of the deep sea floor often require the combined use of optical systems for high resolution and sonar systems for broad areal coverage. Combining such systems in a single vehicle requires the consideration of numerous trade-offs. In the deep-tow system of the marine physical laboratory, several sonar and optical systems are operated by means of an armored coaxial tow cable to depths in excess of 7 km. Power, control signals and data are multiplexed on this single coaxial conductor of this cable. Incorporated in this survey system are side-scan and high-resolution profiling sonars, together with stereo 35 mm film, and slow-scan television cameras. The television system operates in a 'snap-shot' manner, with greatly reduced bandwidth and low power consumption through the use of strobe lighting and scan conversion. The development of these systems and some of their applications and results are reviewed.

Brisken, A. F., Frey, R. L., and Jackson, J. S., **CONTINENTAL LAND MOBILE COMMUNICATIONS AND AUTOMATIC POSITION FIXING VIA SATELLITE**, Carnahan Conference on Crime Countermeasures, Lexington, Kentucky, April 6-8, 1977.

A station wagon was equipped with a specially designed antenna. A slightly modified commercial VHF transceiver, and a digital tone-code communications bandwidth ranging responder. The General Electric Radio-Optical Observatory near Schenectady, N.Y., represented the major earth terminal; a commercial VHF base station with a satellite antenna represented the headquarters or sector office ground station. Communications were relayed by NASA's ATS-3 geosynchronous satellite; both ATS-1 and ATS-3 were used for position fixing. Voice, slow scan television, audio test tones, intrusion sensor data and telephone patches were relayed by the satellite to and from the vehicle under a variety of conditions in greater Washington, D.C., and the southwestern United States. The experiment demonstrated continental communications of a quality equivalent to or better than present line-of-sight VHF capabilities.

Basov, A. N., Odnolko, V. V., and Uzilevskiy, V. A., **THE TECHNOLOGY OF PROCESSING PRINTED INFORMATION,** Elektrosvyaz (USSR), vol. 30, no. 8, pp. 35-38, 1976.

The basic approaches to the application of television techniques for transmitting, processing, and displaying information in the form of printed texts and illustrations are examined. Block diagrams and technical procedures for using slow-scan television equipment for photographing the image on the screen of a television tube are described. Also described are a photo-television equipmet assembly used for symbol-type information, optimization of the color reproducing processes and the electronic scanning of halftone pictures.

Cantella, M. J., McNutt, D. P., **OBSERVATIONS OF SKY BRIGHTNESS SPATIAL VARIATIONS,** Proceedings of the Society of Phote-Optical Instrumentation Engineers, Vol. 91., August 26-27, 1976.

Two dimensional spatial variations of the night sky in the visible spectrum have been observed at the focal plane of the 48-inc` telescope at Cloudcroft, New Mexico. A calibrated, slow-scan intensified television type sensor was used with exposure periods of the order of second. It is believed that these sky brightness variations are not readily observed with film because of temporal smoothing which accompanies the very long exposure periods needed to achieve comparable brightness threshold levels. Instrumentation and test data are described, and speculations are made on the origin of the sky brightness variations and on the imapct on future systems.

Wellman, J. B., Landauer, F. P., Norris, D. D., and Thorpe, T. E., **THE VIKING ORBITER VISUAL IMAGING SUBSYSTEM,** Journal of Spacecraft and Rockets, vol. 13, no. 11, pp. 660-666, 1976.

Deals with a visual imaging subsystem consisting of two slow-scan television cameras which forms part of the scientific payload of each of two Viking orbiter spacecraft photographing the surface of Mars. These cameras are used to evaluate the potential landing sites on Mars, and to conduct other scientific investigations of the planet. The camera was subjected to an extensive test and calibration program prior to launch. Based on this calibration and subsequent analyses, surface resolution exceeding 100 m is expected to be achieved from the periapsis portion of the Viking orbits. The inherent geometric accuracies of the orbiter cameras surpass those of cameras used in previous planetary missions. The analyses of images acquired during the cruise phase of the mission confirm that the cameras have survived the rigors of launch and are performing in a manner consistent with the prelaunch calibrations.

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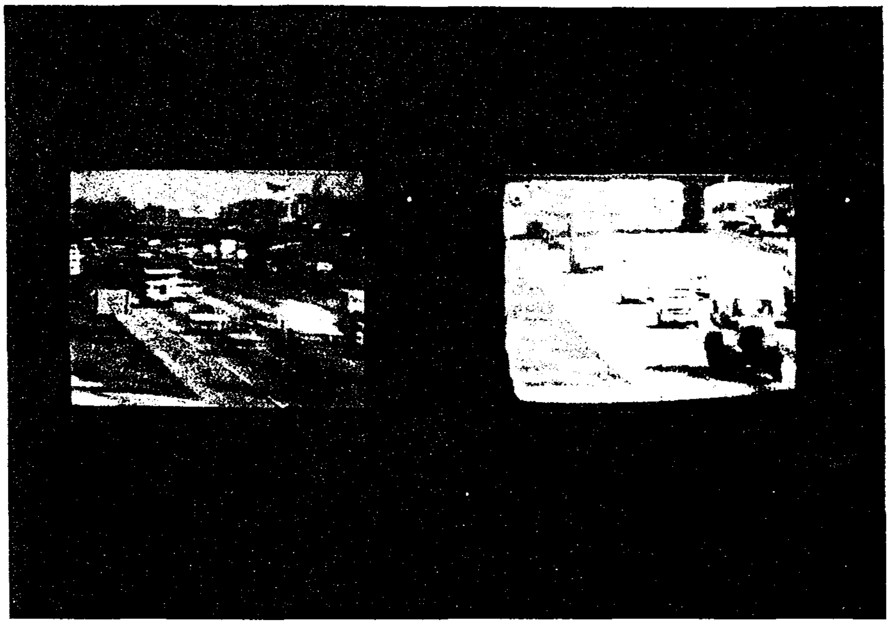
APPENDIX



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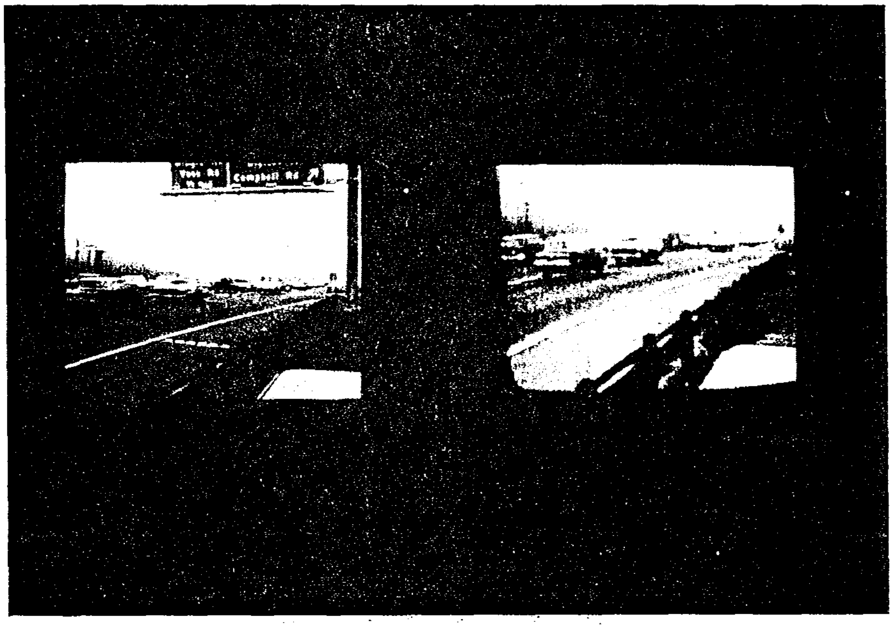

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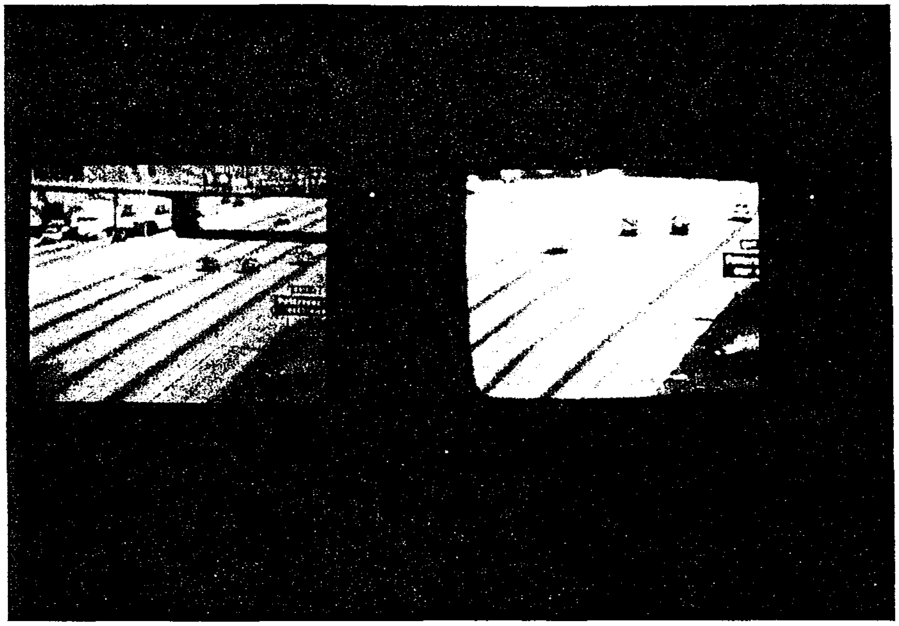

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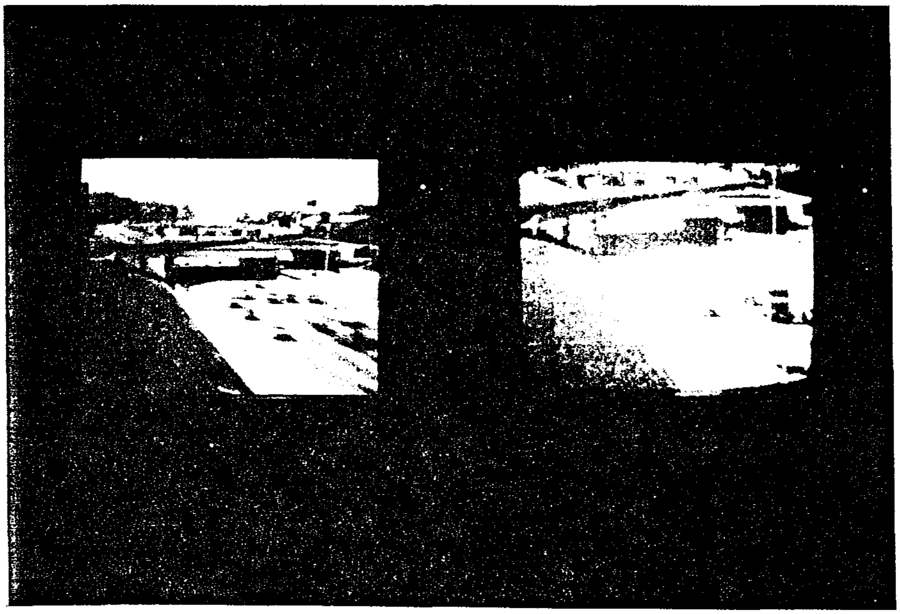

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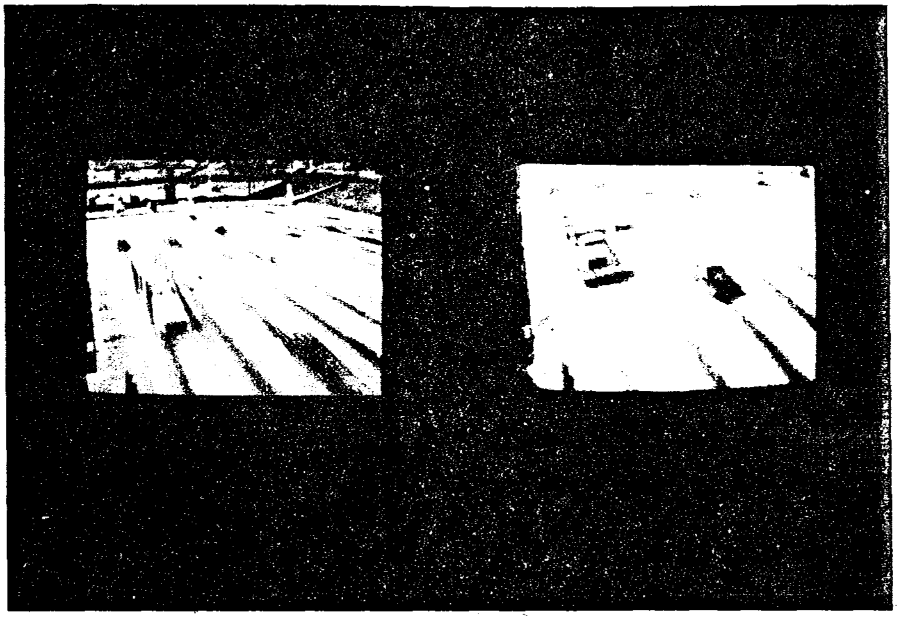

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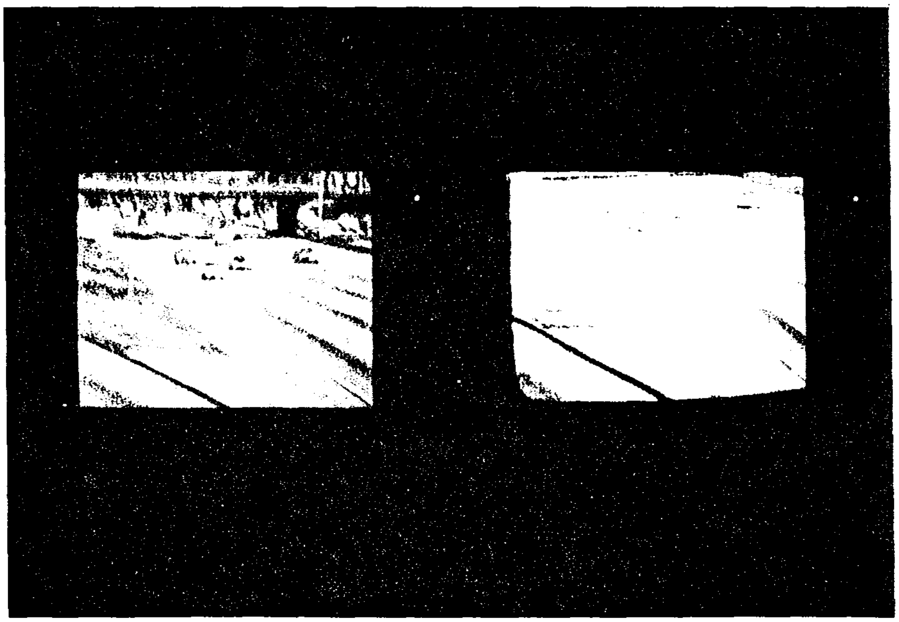

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