Research Report
KTC-02-03/SPR-235-00-1F

KENTUCKY TRANSPORTATION CENTER

College of Engineering

EVALUATION OF 220 MHz FREQUENCIES FOR ITS EXPERIMENTATION

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March 26, 2002

Mr. Jose M. Sepulveda
Division Administrator
Federal Highway Administration
330 West Broadway
Frankfort, Kentucky 40602-0536

SUBJECT: Implementation Statement for KYSPR 00-235, "Evaluation of 220 MHz Frequencies for ITS Experimentation"

Dear Mr. Sepulveda:

The Kentucky Transportation Cabinet implemented a 220 MHz wireless communication system as part of the TRIMARC traffic management system in the Louisville, Kentucky area. The purpose of the subject research effort was to evaluate the use of the 220 MHz system to transmit radar vehicle data collected at the roadside to an operations center. Staff of the Kentucky Transportation Center evaluated the functional reliability and cost effectiveness of the 220 MHz system and recommends additional deployment of the technology for ITS applications within Kentucky.

As a result of this study, the Kentucky Transportation Cabinet will deploy additional 220 MHz wireless communication systems for ITS applications within the state.

Sincerely,

J. M. Yowell

J. M. Yowell, P.E.
State Highway Engineer

JMY/AHJ/CAK

c: Chuck Knowles

EDUCATION PAYS

Research Report
KTC-02-03 / SPR-235-00-1F

EVALUATION OF 220 MHz FREQUENCIES FOR ITS EXPERIMENTATION

by

David Q. Hunsucker
Research Engineer

Kentucky Transportation Center
College of Engineering
University of Kentucky

in cooperation with
Kentucky Transportation Cabinet

and

Federal Highway Administration
US Department of Transportation

February 2002

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16. Abstract

The Kentucky Transportation Cabinet implemented a 220 MHz wireless communication system as part of the TRIMARC traffic management system. The purpose of this research effort was to evaluate the use of the 220 MHz system to transmit data collected at the roadside to an operations center to enable operators to make sound decisions regarding traffic flow within the greater metropolitan area of Louisville, Kentucky. The attributes of the 220 MHz communication system, relative to functional reliability and cost effectiveness of the system were evaluated to determine if further use of 220 MHz technology for ITS applications is warranted.

The performance of the 220 MHz system has, by all accounts, been superb. The reliability of the system has been excellent when compared with conventional phone line service. The 220 MHz system has also proven to be extremely cost effective. The cost data obtained for this study indicate significant cost savings over the life of the project and recouping the initial extra investment practically within the first year after installation.

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EXECUTIVE SUMMARY

The Kentucky Transportation Cabinet implemented a 220 MHz wireless communication system as part of the Traffic Response and Incident Management Assisting the River Cities (TRIMARC) traffic management system in the metropolitan area of Louisville, Kentucky. The purpose of this research effort was to evaluate the use of the 220 MHz system to transmit data collected at the roadside to an operations center to enable operators to make sound decisions regarding traffic flow within the greater metropolitan area of Louisville. The functional reliability and cost effectiveness of the 220 MHz communication system evaluated to determine if further use of 220 MHz technology for Intelligent Transportation Systems (ITS) applications is warranted.

Available literature on 220 MHz data radio and on evaluation of wireless communications applications were reviewed and summarized. A plan to evaluate the 220 MHz system was prepared and Louisville's TRIMARC installation was evaluated in terms of system reliability and cost efficiency. Sufficient data were collected during the course of this project to conclude that using the 220 MHz wireless communication system within the TRIMARC system has proven to be exceptionally reliable and cost effective. Data transfer efficiencies are equal to or better than those achieved with phone lines and modems. While the initial cost for equipment and installation were higher when compared with the plain old telephone system (POTS), the 220 MHz system accrued sufficient cost savings within the first 16 months of the project to offset the initial extra cost. Moreover, using the 220 MHz system as opposed to the POTS, cost savings of about $96,000 is expected over the six-year life of the project.

The performance of the 220 MHz system has been superb. The reliability of the system has been excellent when compared with conventional phone line service. The 220 MHz system has also proven to be extremely cost effective. The cost data obtained for this study indicate significant cost savings over the life of the project and recouping the initial extra investment practically within the first year after installation.

Therefore, as a result of this study, it is recommended that the Kentucky Transportation Cabinet seek additional licenses covering the use of the 220 MHz frequency band for ITS applications within the state.

1.0 INTRODUCTION

The purpose of this research effort was to secure information and data necessary to evaluate the use of a 220 MHz wireless communications system for traffic management within the greater metropolitan area of Louisville, Kentucky. The Kentucky Transportation Cabinet obtained approval to install and operate 220 MHz data radio equipment in Louisville to communicate with radar vehicle detectors. The equipment was operated using frequency pairs that were temporarily assigned for Intelligent Transportation Systems (ITS) experimentation purposes by the Federal Communications Commission (FCC) and the Federal Highway Administration (FHWA). The functional reliability and cost effectiveness of the 220 MHz communication system were evaluated to determine if further use of 220 MHz technology for ITS applications is warranted.

The findings and recommendations from this study will be used by the Kentucky Transportation Cabinet to make informed decisions on the future use of 220 MHz wireless communications technology for transportation applications. In addition, the Cabinet may use the findings of this study to provide recommendations to the FCC regarding permanent frequency allocation.

2.0 BACKGROUND

The FCC recently reallocated the 220 MHz land mobile spectrum, resulting in many new channels, most of which have been auctioned off to the public. The FHWA obtained temporary rights to five frequency pairs in this band, which were set aside for ITS experimentation purposes. An application for two of these frequency pairs was submitted and accepted for use on the TRIMARC incident management project in Louisville, Kentucky. These frequencies were used for communication with radar vehicle detectors, beginning in the Spring of 2000.

3.0 LITERATURE REVIEW

A detailed review of pertinent literature was performed to assess the technical applicability of using 220 MHz wireless communications in traffic management schemes. Dr. James V. Krogmeier, a professor at the Purdue University School of Electrical and Computing Engineering, has conducted the principal research in this area. Results of Dr. Krogmeier’s research indicate that the 220 MHz is functional and capable to be used in Intelligent Transportation Systems (ITS).

The main focus of Dr. Krogmeier’s research was to design, field test, and deploy a digital radio that used the 220 MHz spectrum to support point-to-point data communications applications. The research team’s main objective was to control a wireless modem that was located 1.5 miles from the control center.

Due to the limitation of the bandwidth provided by FCC, high-efficiency modems are needed in order to complete the same tasks performed by wire line modems. This is due to the impairment (fading, multipath, etc.) in the radio channel. There is a significant amount of technical information contained in the Purdue report that is not included in this report but is available for further review.

Based on his research, Dr. Krogmeier concluded that future uses of 220 MHz wireless communications might include:

1) Data communications between highway infrastructure such as radar, video cameras, weight center for trucks, etc.
2) Mobile incident response vehicles, i.e., police, fire, ambulances, emergency rescue, etc.
3) Transmission of surveillance sensor telemetry to remote concentrators.
4) Multiple access communications in semi-rural adaptive traffic signal coordination.

Georgia officials attempted to use 220 MHz wireless communications for traffic management during the 1996 Olympic Games held in Atlanta. That attempt was largely unsuccessful for two reasons. Video transmission and electronic toll collection require data rates that could not be supported on narrowband channels and, production modems capable of efficiently using these narrow band channels were not available.

In summary, the literature review indicated the principal reason for the unsuccessful use of 220 MHz for wireless communications was due to inefficient modems. However, present day modulation and demodulation techniques being used in 220 MHz spectrums can eliminate the noise along the wireless transmission, making it perform as well as communications conducted over wire lines. This method enables clear communication between the data and the detector with the minimal interference. A bibliography of the articles reviewed for this report is included herein. A brief history of the use of 220 MHz for wireless communications is included in Appendix A.

4.0 EVALUATION OF 220 MHz WIRELESS COMMUNICATION SYSTEM

In 1998 the Commonwealth of Kentucky and the State of Indiana cooperatively developed the Traffic Response and Incident Management Assisting the River Cities (TRIMARC) traffic management system for Louisville, Kentucky and the southern Indiana urbanized area to the north and west of Louisville. This area was rated as one of the top 50 congested areas in the nation. The TRIMARC traffic management system was planned in response to FHWA's plans to deploy ITS to the 75 largest metropolitan areas in the nation to reduce traffic congestion. The system was designed to improve safety, emergency response, travel time and air quality in the greater Louisville metropolitan area. The traffic monitoring system was estimated to cost \$9 million. Federal Highway funds from the Congestion Mitigation and Air Quality category, only to be used for projects that improve air quality and mitigate congestion without adding additional lanes, were used for the TRIMARC project. The river cities that have benefited from the new system included Louisville, Kentucky, and New Albany, Clarkesville and Jeffersonville, Indiana. It is generally agreed that the system is improving traffic flow along the high-volume Interstate 65 corridor by providing timely and accurate traffic information. This information assists public safety agencies to better respond to freeway incidents and helps motorists find alternate routes during traffic congestion.

The Kentucky Transportation Cabinet awarded a contract to TRW, Inc. to develop a traffic management system. TRW was ultimately responsible for design, construction, system integration, operation and maintenance of the traffic management system until the final transfer to the Kentucky Transportation Cabinet, expected in 2007. Twenty-four video surveillance cameras, 45 wide-beam radar locations, and five loop detectors/classifiers were placed along the I-65, I-64 and I-71 corridors to determine real-time information such as speed, volume, and vehicle classification. The information is fed to an incident management control center operated by TRW and located on Main Street near the river in downtown Louisville. Information is relayed to the public via 11 variable message signs located along I-65, I-64 and I-71, through highway advisory radio and by real-time web sites. TRW also provides needed traffic information to the media, public transit and other public agencies for their use. Detailed reference markers are displayed every two-tenths of a mile to improve the ability of emergency response teams to locate an accident.

The 220 MHz radio modems for the TRIMARC project are used to transmit traffic data to the TRIMARC Operations Center from 44 sites. The radio modems are manufactured by Microwave Data Systems of Rochester, New York. The KYTC chose to use the MDS 2710 model for data transmission based upon previous experience with the company's products. Data from the wide-beam radar is sent to a base station located at the University of Louisville's Medical Center via radio modem after being polled. Each radio modem is polled every 30 seconds. The base station picks up the RF signal from the transceivers located at the roadside and relays it to the operations center over leased telephone lines.

Personnel within the TRIMARC Operations Center declared that the performance of the 220 MHz radio system has been exceptional, certainly comparable to, if not better than, using phone lines and modems for data transmission. There have been less failures observed with the radio transmission system than occurred with the plain old telephone system (POTS). However, configuration of the radio system is only somewhat more difficult than conventional modems. According to TRW personnel, the MDS 2710 radio modems have proven to be highly reliable. They have had to replace only a single unit during the first three years of the project, while, at the same time period, they have replaced three of the conventional modems.

The cost effectiveness of the use of wireless communications for transmission of data to the operations center versus using landlines is confirmed by examining fixed costs and recurring cost incurred initially and then over the life of the project. Appendix B contains a cost comparison of TRIMARC's POTS system and the 220 MHz system. The fixed cost of both systems includes the initial equipment costs and the cost of the installation. Recurring costs include monthly and/or yearly charges normally incurred for operations and maintenance of the systems. The initial cost for the POTS, assuming 45 modems were purchased (includes one spare) and 44 lines were installed, was $52,590. The initial cost for the 220 MHz system was somewhat higher, as expected. The initial cost for the field site and the base station amounted to $80,920. However, the cost savings of using the 220 MHz system are realized when considering the annually recurring cost. Annual costs to operate the POTS would be expected to be about $23,595 while the 220 MHz system would only be about $2,880 annually. As can be seen, the cost savings from implementing the RF modems for data transmission on the TRIMARC project are significant. It would take approximately 16 months for the extra initial cost of the 220 MHz system to be offset by savings accrued from monthly savings. When projected over the six-year life of the project, the 220 MHz system will result in savings of roughly $96,000 over that of the POTS.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Sufficient data were collected during the course of this project to conclude that using the 220 MHz wireless communication system within the TRIMARC system has proven to be exceptionally reliable and cost effective. Data transfer efficiencies were equal to or better than those achieved with leased phone lines and modems. While the initial cost for equipment and installation were higher when compared with the POTS, the 220 MHz system accrued sufficient cost savings within the first 16 months of the project to offset the initial extra cost of the system. Moreover, using the 220 MHz system will result in expected cost savings of approximately $96,000 over the six-year life of the project.

Therefore, it is recommended that the Kentucky Transportation Cabinet seek additional licenses covering the use of the 220 MHz frequency band for ITS applications within the state.

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APPENDIX A

History of 220 MHz Wireless Communications

History of 220 MHz for Wireless Communication

1988, Federal Communications Commission (FCC) reallocated 220-222 MHz band from the Amateur Radio service to private and federal government land mobile use.

1991, 220 MHz is formally established under Subpart T of Part 90 of the FCC's rules.

1992, Five narrow band (4 kHz) frequency pairs in the 220-222 MHz band were allocated for ITS applications.

July 29, 1993, Mr. Kingdon R. Hughes (Rush Network) was awarded a nationwide five-channel, 220 MHz radio license.

1996 Olympic Games, Atlanta, Georgia (failure)

March 12, 1997 and March 21, 1998, FCC promotes the development of advanced radio technologies.

1997 and 1998, FCC eliminates most of the bands unnecessary regulatory burdens and greatly enhances the competitive potential of the 220 MHz service.

APPENDIX B

Cost Comparison for the POTS and 220 MHz System

TRIMARC POTS System

Fixed Cost		Unit Cost	Qty	Extension	Notes
Field Site					
	Zypcom Modem	$1,022.00	45	$45,990.00	One spare
	Installation	$150.00	44	$6,600.00	
Subtotal				$52,590.00	
Recurring Cost					
	POTS Lines/month	$44.69	44	$1,966.36	
Annual Subtotal				$23,596.32	

Operational Cost Analysis

Year	Incremental Cost	Cumulative Cost
1	$76,186.32	$76,186.32
2	$23,596.32	$99,782.64
3	$23,596.32	$123,378.96
4	$23,596.32	$146,975.28
5	$23,596.32	$170,571.60
6	$23,596.32	$194,167.92

TRIMARC 222MHz System

Fixed Cost		Unit Cost	Qty	Extension	Notes
Field Site					
	Radio	$1,245.73	45	$56,057.85	One spare
	Antenna	$183.77	45	$8,269.65	One spare
	Cables/Coax/Misc	$6,141.55	1	$6,141.55	
Base Station					
	Radio	$1,245.73	2	$2,491.46	
	Omni Antenna	$183.77	2	$367.54	
	Labor/Misc	$7,290.34	1	$7,290.34	
	Installation	$150.00	2	$300.00	
Subtotal				$80,918.39	
Recurring Cost					
	Leased Lines/month*	$120.00	2	$240.00	Relay from U of L to TRIMARC
Annual Subtotal				$2,880.00	

* Not required for standard installation

Operational Cost Analysis

Year	Incremental Cost	Cumulative Cost
1	$83,798.39	$83,798.39
2	$2,880.00	$86,678.39
3	$2,880.00	$89,558.39
4	$2,880.00	$92,438.39
5	$2,880.00	$95,318.39
6	$2,880.00	$98,198.39

Operational Cost Analysis (continued) Expected Yearly Savings			
Year	Cumulative Cost 222MHz System	Cumulative Cost POTS System	Cumulative Yearly Savings
1	$83,798.39	$76,186.32	($7,616.07)
2	$86,678.39	$99,782.64	$13,104.25
3	$89,558.39	$123,378.96	$33,820.57
4	$92,438.39	$146,975.28	$54,536.89
5	$95,318.39	$170,571.60	$75,253.21
6	$98,198.39	$194,167.92	$95,969.53