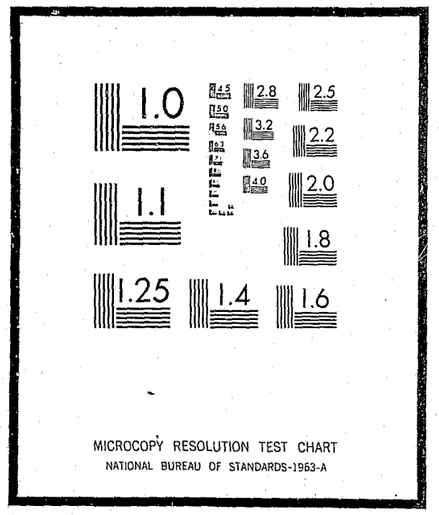




# A communication system for the Washington, D. C. metropolitan police department *

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## INTRODUCTION

Recent governmental studies have created an awareness for the need for improvement in the Washington, D. C. Metropolitan Police Department communications system. To meet this need, a requirements study was undertaken. The study was organized to evaluate the present system, determine present and future needs, and recommend a system which will satisfy the requirements of the police department for future years. At the outset of the study, Metropolitan Police Department officials were interviewed, the existing communication facilities were inspected and radio field strength measurements were made. Also, other police departments were visited and computer-assisted system loading studies were initiated. This paper will present a summary of the results of the study including those major features of the proposed communication system which may be selected for implementation.

### *Description of the present communications system*

Presently, the Metropolitan Police Department operates four voice communications networks, a teletype facility and various private telephone lines and radio monitoring facilities.

The four voice communications systems are:

1. vehicular radio network,
2. footman's radio system,
3. point-to-point radio circuits, and
4. portable radio network.

#### Vehicular radio network

The vehicular radio system, consists of a radio control room, 2 base transmitter sites and approximately 376 mobile units assigned to scout cars, cruisers, cranes, the traffic division, patrol wagons, harbor patrol boats and motorcycles. To control the above units, 3 duplex radio channels in the 150 MHz band are available.

The city of Washington, D. C. is divided into 14 police precincts. For radio communication, the 14 precincts are divided into 2 radio zones, each zone being controlled by one radio channel. The third channel is used for citywide coverage and shared by detective and traffic units. Six control consoles are arranged in a "U" shaped configuration in the radio room. All six consoles have identical telephone terminals and radio controls. The two radio zones are handled from these positions. Four of the dispatchers answer incoming telephone calls and assign mobile units via the appropriate channel. Two positions are designated as "hot seat" posts. The dispatchers at these positions receive dispatch forms for mobiles sent out by the other four operators and it is their task to handle field inquiries from these mobiles and terminate mobile assignments. The third radio channel is controlled from one console position inside the "U" shaped array. Three auxiliary telephone answering positions are also located in this area.

Two status boards are available for keeping track of mobile units. These boards are maps of the area with numbered lights, corresponding to mobile units in patrol areas, mounted on them. Duplicate controls for the lights are installed on the dispatchers' consoles. Adjacent to the radio room is a supervisors office. This office contains a large radio console, a status board which is a duplicate of the one in the radio room, and several private telephone lines in addition to all controls available to the dispatchers in the radio room. Therefore, any activities within the radio room can be monitored and, if necessary, controlled from the supervisor's console.

#### The footman's radio system

This system is controlled at the precinct level. It consists of a base transmitter remotely located within the precinct being served and individual portable units strapped to the belt of each foot patrolman. The port-



*Interim report on the Metropolitan Police Department project to study and redesign the police communications system. Project, supported by OLEA Grant 071, is expected to provide a model system format for other large city police departments.

able unit is set up as a selective call, tone coded transmitter and receiver. Two duplex channels in the 150 MHz band are used in the footman's system. There are seven precincts on each channel and voice communication can be established between footman and base on the duplex link or footman to footman in simplex mode. The base receiver for each precinct is tone coded to correspond to the units working in that precinct.

### Point-to-point radio circuits

The point-to-point network in which the police department participates includes the following agencies:

Fairfax County Police, Arlington County Police, U. S. Park Police, Alexandria Police, Montgomery County Police, Maryland State Police, Prince Georges County Police, and Armed Forces Police.

The control console for this network is in the radio supervisor's office. All agencies on the 450, MHz channel are equipped with tone coded selective call units.

### Portable radio network

There are approximately 27 portable units available for civil disturbances work. One simplex channel in the 150 MHz band is used in this network. Output power of the quipment ranges from 1 to 10 watts.

### *Proposed system configuration*

Because of the large number of vehicles which will require radio communication, an attempt was made to divide the group according to function and then provide as much flexibility as possible for links within each group. The projected number of vehicles is given in Table I. This projection is based on studies and recommendations made by an independent consultant group and reflects partially the trend toward placing foot patrolmen in mobile scout units. The total number of 550 mobiles is an increase of 60 per cent over those currently operating the police department.

The frequency allocation plan for all mobile units is illustrated in Figure 1. In this system the city is divided into three zones, each one being handled by one primary duplex channel. Another duplex channel is available for citywide coverage (CWI). Mobiles working on these four channels would also have portable units to provide communications for officers when they are temporarily outside their cars. Two other citywide links are provided to handle the expected volume of radio traffic, CWII and CWIII. The Civil Disturbance Units would operate in a portable network on a separate frequency.

Table I
Projected Number of Vehicles for the
Washington, D.C. Metropolitan Police Department

| | | |
|---|---|---|
| *Function 1* | (Patrol and Investigation) | |
| | Scout Cars | 170 |
| | Tactical Division Cars | 35 |
| | Canine Cars | 20 |
| | Wagons | 15 |
| | Detective Cruisers | 100 |
| | | 340 |
| *Function 2* | (Traffic) | |
| | Accident Investigation Units | 15 |
| | Traffic Cars | 20 |
| | Motorcycles | 50 |
| | Special Detail (Motorcycles) | 15 |
| | | 100 |
| *Function 3* | (Administrative and Special) | |
| | Administrative Curisers | 30 |
| | Morals Division | 20 |
| | Youth Aid Division | 20 |
| | Mobile Laboratory | 5 |
| | Buses, Vans, Boats, Morgue | 35 |
| | Wagons, Cranes | 110 |
| | Total | 550 |

Even though it is believed that the use of foot patrolmen will be de-emphasized, those remaining in service and those who may ride scooters should be provided with some means of radio communication. In order to do this, the retention of one of the footmen channels would be desirable. In this plan as shown in Figure 1 one footman, duplex channel is used. When the duplex portion of the channel is activated the portable transmission is received by a tone coded satellite receiver and the message is relayed to the communications center via land line. This system would require that the repeaters in each zone be receptive only to tone coded portables operating in that zone. This system will also be used by mobile personnel when they are operating outside their vehicles. Now that the basic allocation plan has been presented, the primary and alternate channel assignments can be considered.

Channel assignments have been proposed which take into consideration such things as hardware limitations, maximum utilization of existing equipment, and mobile unit integration along functional lines. In order



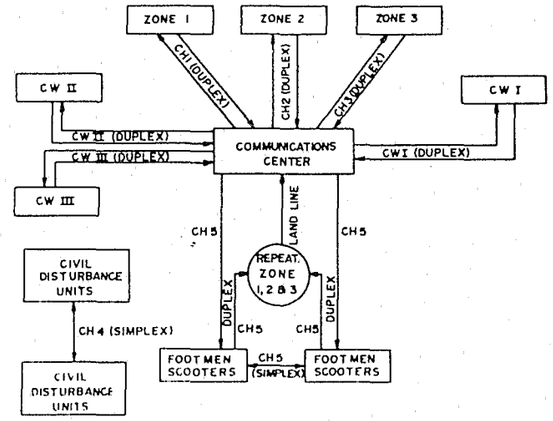


Figure 1 Mobile unit frequency allocation plan

to provide sufficient channel capacity without proposing an overly complex system, it was assumed that four additional frequencies in the 150 megahertz band would become available and these frequencies were used with those previously obtained to design a communication system. Four of the additional frequencies used are 159.240, 159.270, 159.330 and 159.360 megahertz. These frequencies are normally reserved for use by the forestry service but an effort is being made to obtain a waiver for their assignment for public safety application in the Washington, D. C. area. A frequency allocation diagram for the system is shown in Figure 2. Starting from the top of this figure, the first four blocks show the mobile unit frequencies proposed for those units tabulated under function 1 in Table I. Approximately 60 units would be assigned to each of three patrol zones. Each of these units would operate on a zone channel and be capable of switching to the alternate channel, CWI. Conversely, the vehicles on CWI could operate on any of three alternate channels making them compatible with patrol vehicles in the zones. CWII is used as a duplex channel for traffic control and CWIII has been set up for administrative work and to provide communications for various divisions and maintenance functions. The alternate channels available give all mobile units the capability of operating on CWI.

Those administrative personnel who work directly with the people operating in the three zones in the traffic division, or on CWI should be equipped with mobile units tuned to the appropriate channels. This would have the effect of dispersing the 30 administrative units throughout the six available channels, thus relieving the work load on CWIII somewhat. It should be noted though, that with a total of six channels, it would be extremely difficult to give any one mobile

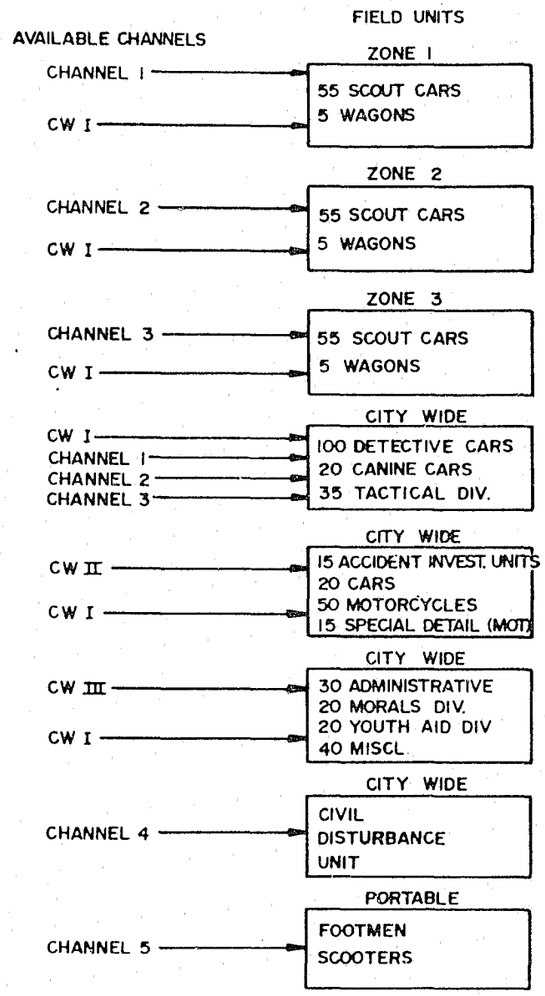


Figure 2 Frequency allocation diagram

unit the ability to monitor radio activity for the entire force. Communications for the footmen or scooters will be controlled from the communications center rather than at precinct level with the installation of additional equipment as indicated in Figure 1.

Radio links in the system would be handled in the communications center in the following manner, assuming telephone central office zoning is not in effect and that radio dispatching and telephone call handling techniques are not changed:

Consoles controlling channels one through three and CWI would share a conveyor belt. There would be three consoles per channel. Any of the four channels in this group could be controlled from any of the twelve console positions, however, in practice one of

the three operators on each channel would answer field inquiries and check mobile units in after assignments had been completed. This "hot seat" operator would also assign report numbers to units as needed. The other eight dispatchers would intercept incoming calls and assign mobile units on any of the three channels or CWI. They would then send the dispatch ticket to the "hot seat" operator handling the appropriate channel, via conveyor belt. For field inquiries requiring teletype data or computer stored data, a radio dispatcher would use the conveyor belt for access to the computer console or the teletype room. If the action were required on CWII or CWIII, the dispatcher would make out a card and send it to the consoles controlling those channels.

CWII and CWIII links would be controlled in a manner similar to that used for the functional group described above. It is believed that a group of four consoles would be sufficient to handle these two channels. Two additional consoles would be manned by clerks to handle telephone overflow and keep radio room logs. Sufficient space will be provided in the radio room for the addition of two more radio consoles and several land line positions along the conveyor belt. It should also be noted that six status display panels have been provided. Four duplicate panels would keep track of mobile units in zones one, two, three and on CWI. The other two duplicate panels would indicate the status of mobile units on CWII and CWIII.

Car-to-car communications would take place at the discretion of a console operator who could place any channel in full-repeat mode so that all transmissions from mobile units would be simultaneously rebroadcast on the base station frequency.

*Communications center*

The main features of the proposed communications center will be briefly described in this section. Four functional areas within the communications center are the radio room, the monitor room, the emergency room and the teletype room.

**Radio room**

Figure 3 is an end view of the radio room. The shaded wedge indicated a dispatcher's view of one of the status display boards. Dispatchers would be seated at consoles placed front-to-front sharing a conveyor belt as shown in Figure 4, the radio room perspective layout. All console positions have access to the conveyor belt which also has a drop in the teletype room. This belt can be used to shuttle data between any of the drop positions. Radio dispatching and telephone answering procedures have been covered in the previous section.

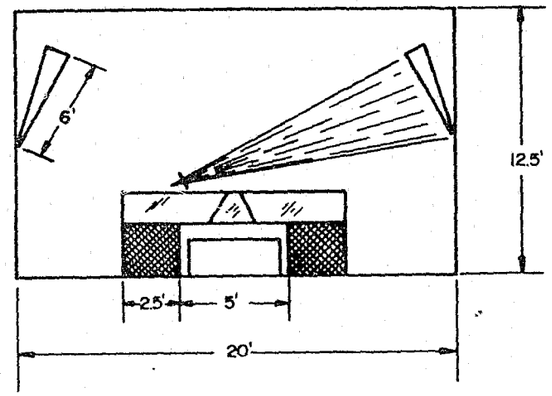


Figure 3 – Radio room end view

Each of the consoles, with the exception of the computer operator's console will have a 60 line telephone panel with "touch tone" units for dialing. In addition to the normal radio controls, each console will have audio monitor speakers for all channels which can be controlled from that position. Muting controls will be provided for these monitors with an inter-lock so that it will not be possible to have any specific channel not monitored by a speaker. It will also be possible to use a head set speaker and microphone at the consoles if desired. Insertion of a phone plug for a head set would disable the panel-mounted speaker and microphone being used. Controls for the metropolitan area point-to-point radio system will be at each console "hot seat" position for zones 1, 2, 3, CWI and at the supervisor's console. Consoles 19 and 20 will be manned by clerks who will keep the radio room log and answer telephones from the precincts or the public as the work load dictates.

The four status display boards on the right in Figure 4 will be identical. They will have capacity for indicating the status of 350 vehicles operating in zones 1, 2, 3 and on CWI channel. The two boards on the left will also have a capacity for 350 vehicles and will be used by the console operators working CWII and CWIII.

A sample floor plan for the communications center is shown as Figure 5.

**Monitor room**

The radio monitor room adjacent to the radio room will serve two functions. During normal police routines it would be possible to monitor any of the communication circuits used in the radio room to check on circuit discipline and as a training aid for personnel. A tape recorder would be used to retain all voice



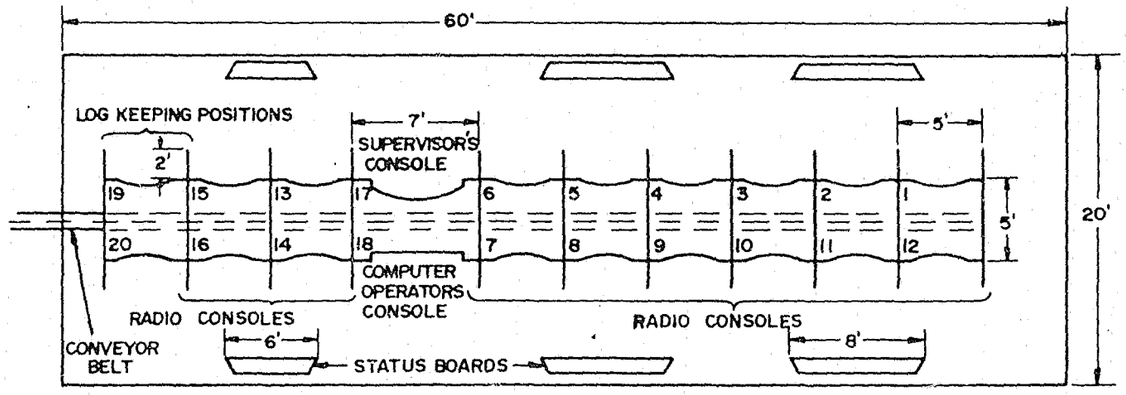


Figure 4 – Radio room layout

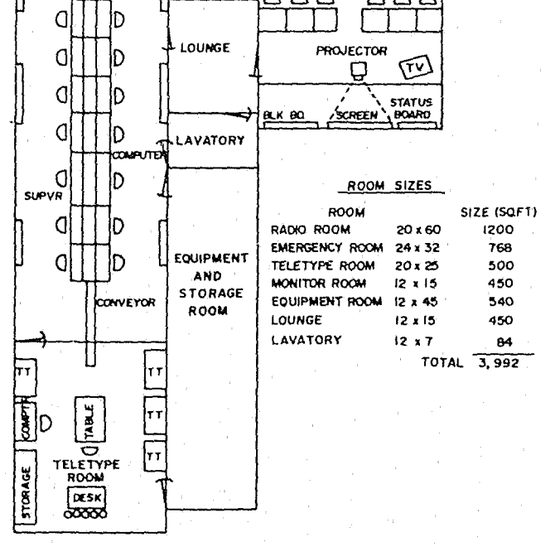


Figure 5 – Communications center sample floor plan

communications on radio and telephone circuits. In an emergency situation, selected police radio communication links could be controlled from this room. In addition, radio link or telephone terminals for all participating public service agencies would be available at this location so that this room would become a central communications room for personnel working in the emergency room.

**Emergency room**

Presently the Metropolitan Police Department has an emergency control center in Lorton, Virginia. The primary purpose of this center is to coordinate civil defense efforts in case of nuclear bombardment of Washington, D. C. For situations such as riots and large fires, it would be desirable to gather together representatives from the Metropolitan Police Department, Fire Department, Gas Company, Public Water Service, Park Police, Electric Company and so on at a location in central Washington, D. C. The goal would be to have, in one room, key personnel from various organizations so that they could work together and also have available communication links to their respective units. In addition, interested observers or people who might be called for standby duty would be readily available should assistance or advice be needed.

Each of the twelve consoles would have telephone and intercom equipment. The telephones would have available a selection of private lines to all participating agencies and a number of *outside* lines. Intercom units would be used for local communications with other console positions, selected offices within the police headquarters building, operators at the status board, projector position, or map and to speak to the operator in the radio monitor room.

Provisions have been made to keep track of events by using a status board of some type, most likely a black board, a large city or metropolitan area map which could be covered with overlays for marking with grease pencil, and a projector with screen. Intercom jacks would be placed at locations where personnel updating the status display system could be given instructions via headsets if necessary. It would also be possible to install a large TV receiver for

monitoring either commercial broadcasts or for displaying video tapes made on a closed-circuit TV system if the equipment is acquired in the future.

**Teletype room**

Services provided by the teletype facility will remain essentially unchanged. There are three networks which have terminals within the teletype room. A local network ties together all the precincts, the canine division, harbor precinct and the traffic division. A metropolitan area net includes all those agencies sharing the point-to-point radio network. Finally, there is a terminal tied to the National Law Enforcement Teletype system. In the near future, a data link with the FBI central computer may be installed in the teletype room.

*Analysis*

Two primary sources of input data were used for the analysis of the radio traffic for the period April 3 through April 9, 1966. Audio tapes of all radio communications were studied and dispatcher complaint cards, which contain pertinent information concerning every assignment made by radio, were processed by a high speed computer. The audio tapes were used to sample message lengths and contents. Circuit discipline and the use of the "10" series codes indicate that radio time was being fairly well utilized. The observed distribution of message lengths is shown in Figure 6 and compares favorably with those measurements made for other metropolitan communication centers. The average message length was 7.9 seconds and the average time of the total call was 11.9 seconds.

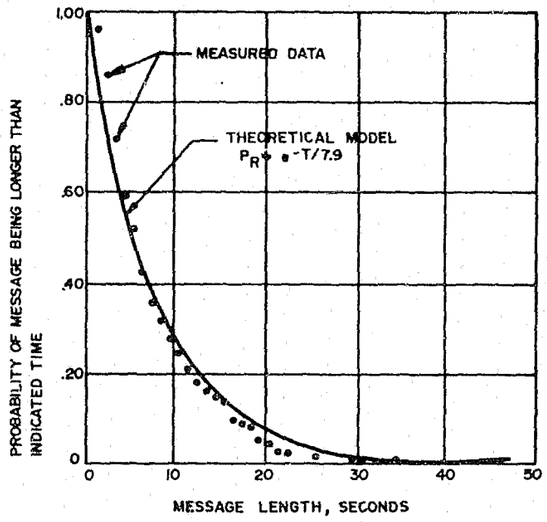


Figure 6 – Distribution of message length

The channel usage factors determined from the audio tapes were compared with the number of assignments for a given hour as determined from the complaint card study. The results indicate a clear relationship as can be seen in Figure 7. The only serious deviation from the pattern occurred at 11:00 p. m. and 12:00 midnight. The audio tapes indicate very high usage udring this period but the complaint records showed fewer assignments than expected. The validity of the data for this period was considered questionable and they were not used in this analysis.

The relationship pictured in Figure 7 indicated that there is approximately 15 minutes of channel time (total for both channels) per hour used in nonassignment calls. The correspondence can also be used to show that on the average, each assignment requires approximately 38.2 seconds of channel time.

*Table II*
*Mobile Unit*

| | *Scout* | *Partol wagon* | *Cruiser* | *Traffic* |
|---|---|---|---|---|
| Per cent of total Assignments | 76.0 | 10.8 | 7.4 | 5.7 |
| Average number of Assignments per car per hour | 0.98 | 0.79 | 0.25 | 0.60 |
| Channel time required per hour (sec) | 37.4 | 30.2 | 9.6 | 22.9 |
| maximum number of cars per channel | 48 | 60 | 182 | 79 |



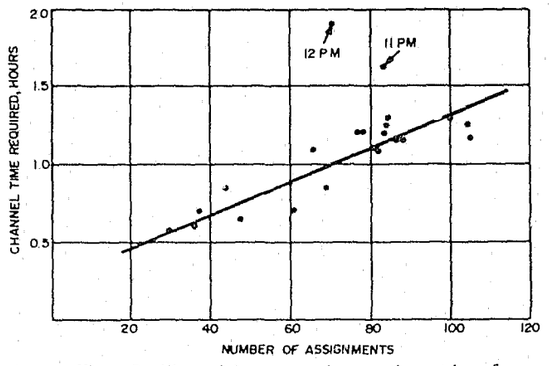


Figure 7 – Channel time required versus the number of assignments

The dispatch complaint card study revealed that approximately 76 per cent of the assignments made by radio are to scout cars and that each scout receives on the average of 0.98 assignments per hour during the peak shift, that is, each scout requires about 37.4 seconds of channel time per hour. Thus using 50 per cent usage as the saturation level, the maximum number of in-service scout cars that should be assigned to a given channel is 48. The data were further separated to determine the same requirements for patrol wagons, cruisers, and traffic vehicles. The results are listed in Table II. Thus it is concluded that a single duplex channel can accommodate 48 scout cars, or 60 patrol wagons, or 182 cruisers, or 79 traffic vehicles if these units continue to use channel time as they did in April 1966. It should be noted that the impact of increased use of one man scout cars has not been considered.

**Development of mathematical model**

The operation of channels in a channel-zoned system is independent. Thus, the most convenient approach is to develop the model for a single channel and take advantage of the independence to extend the results to a system involving several channels.

The model for a single channel is given as

$$P_n(t) = \alpha^n P_0(t)$$

where:

$$\alpha = \frac{\textit{rate of new calls}}{\text{call completion rate}}$$

$P_0(t)$ = probability of channel being free

$P_n(t)$ = probability of n calls in the system (waiting + in service) at time t

The expected average number of calls in the system (waiting + in service) for such a channel is given by

$$L = \sum_{n=0}^{\infty} n\, P_n(t) \quad = \frac{\alpha}{1-\alpha}$$

Thus if there are c channels operating independently, but similar, the expected number of calls at any given time in the system (waiting + in service) is

$$L_c = \frac{c\alpha}{1-\alpha}$$

Now let $Q_c$ represent the number waiting for service in a c channel system. Then $L_c$ and $Q_c$ are related by the following formula:

$$L_c = Q_c + c\alpha$$

Solving this expression for $Q_c$ leads to

$$Q_c = L_c - c\alpha$$

or

$$Q_c = \frac{c\alpha^2}{1-\alpha}.$$

In a public service radio channel it is most important that the time a message is in the system prior to transmission be held to a minimum. This can be accomplished by minimizing the number of calls waiting for service, i.e., $Q_c$. Thus $Q_c$ is an effective measure of the efficiency of a channel zoned communication system.

The above expression for $Q_c$ can be modified to consider the total hours of channel usage expected during a peak hour. If $\alpha$ is the channel usage factor and c is the number of channels, then the total hours of channel time represented is given by

$$t = c\alpha.$$

Solving this expression for $\alpha$ and substituting in the previous expression for $Q_c$ leads to

$$Q_c = \frac{t^2}{c-t}, \quad t<c.$$

where:

t = total hours of channel usage,
c = number of channels.
This expression is plotted for various values of t and c in Figure 8.

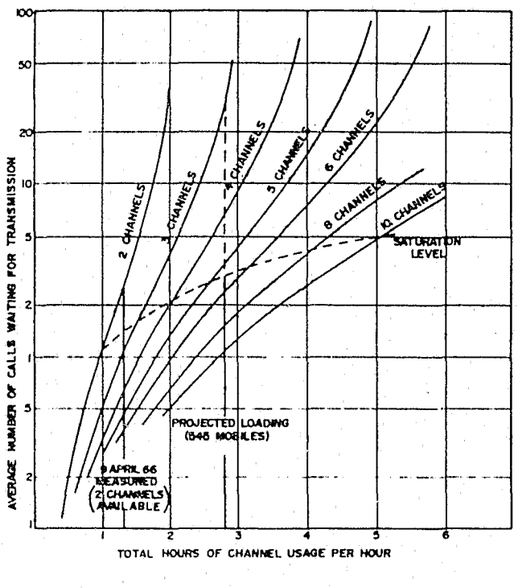


Figure 8 – Average number of delayed calls in a channel-zone system

In order to better use this formula a critical value of $Q_c$ has to be introduced. It was mentioned previously that the usage factor for a public safety radio system should not exceed 0.50. Thus the saturation value for $Q_c$ is given by

$$Q_c = \frac{c\,(0.5)^2}{1-0.5} = 0.5_c$$

The saturation curve is plotted for comparison in Figure 8.

When two channels were in use there was a peak hour requirement of 1.34 hours. The $Q_c$ for this condition is 2.73 which is considerably above the saturation level of 1.0. The addition of a third channel reduced to $Q_c$ to 1.09 which temporarily relieved the congestion. The growth margin for the three channel-zoned system is negligible in that an additional 10 minutes of channel time during the peak hour will bring it to the saturation point.

According to plans there will be approximately 545 vehicles made available to the police department in the next few years. Under the assumption that the channel time requirements per car will be the same as those observed in this study and reported in Table II, the total channel time to support the 545 vehicles can be estimated. That time is 2.85 hours and as seen in Figure 8 at least six channels will be needed to handle the additional load.

In addition to considering a conventional communications system, a channel sharing system was investigated in which the trunking advantages of selective call mode were presented. It was noted that the channel sharing system had very good work load characteristics especially because it was self-equalizing. However, when applied to public safety needs, this system was found to be not as desirable as a conventional system offering full base station repeater operation.

## ACKNOWLEDGMENT

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The authors wish to acknowledge the support of Inspector James J. McAuliffe in arranging interviews with other major police department personnel and supplying records and communications data for our analysis.

The opinions of the project personnel are reflected in this paper and the final design has not been determined at this time. This paper should not be considered as a description of the communications system which will definitely be implemented, but rather as a preliminary design which has not been officially adopted by the Metropolitan Police Department.

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