Government
of Canada

Department of Communications

LAND MOBILE SYSTEMS CONCEPTS FOR THE 900 MHZ BAND

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Telecommunication Regulatory Service

INTRODUCTION

In the United States, the rapid growth of the Land Mobile Services, in the heavily populated areas, has led the Federal Communications Commission (FCC) to take definite steps, first to alleviate the present congestion problem in the Land Mobile service and then to find a long-term solution which would be satisfactory for at least the next 2 decades.

Pressured by the Land Mobile (LM) industry, the FCC, in 1968, initiated proceedings in the form of 2 very important Dockets (18261 and 18262) with the issuing of a "Notice of Proposed Rule Making and Notice of Inquiry". A brief summary follows:

Docket 18261 - Short term relief

The "First Report and Order" adopted by the FCC in May 1970 provided immediate relief to the LM services. The docket allowed the LM services to share portions of the spectrum presently allocated to UHF-TV channels 14 to 20 inclusive, that is, the frequency band 470 - 512 MHz.

Docket 18262 - Long term relief

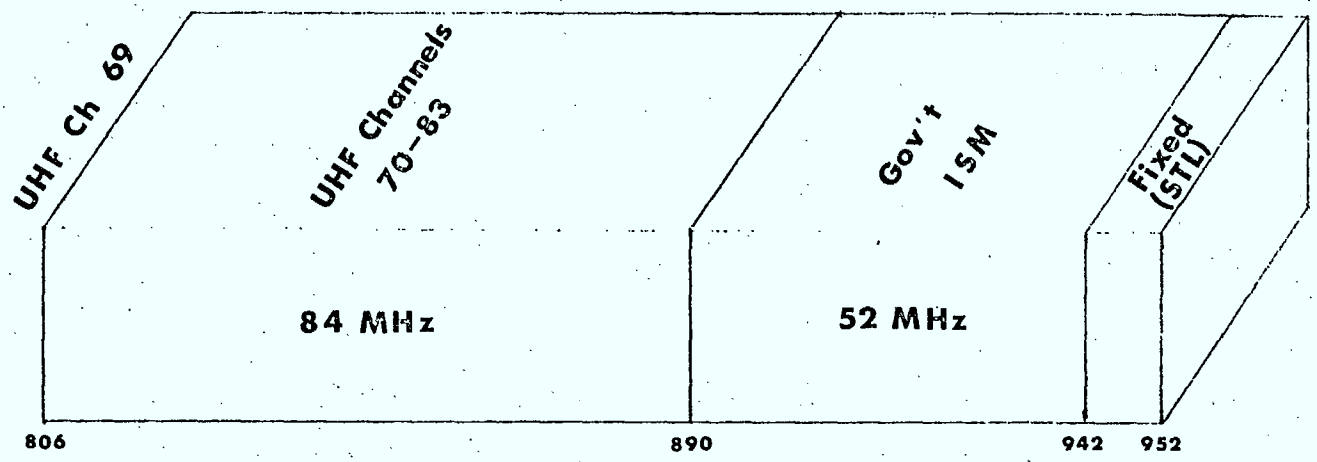
Also in May 1970, the "First Report and Order and Second Notice of Inquiry" on Docket 18262 was issued.

The First Report and Order accomplished a general reallocation of spectrum in the 806 - 947 MHz band with the effect of providing an additional 115 MHz of spectrum to the land mobile radio service. It also provided a tentative sub-allocation of 75 MHz for the development of high capacity common carrier mobile communication systems and 40 MHz for the development of efficient private and shared systems.

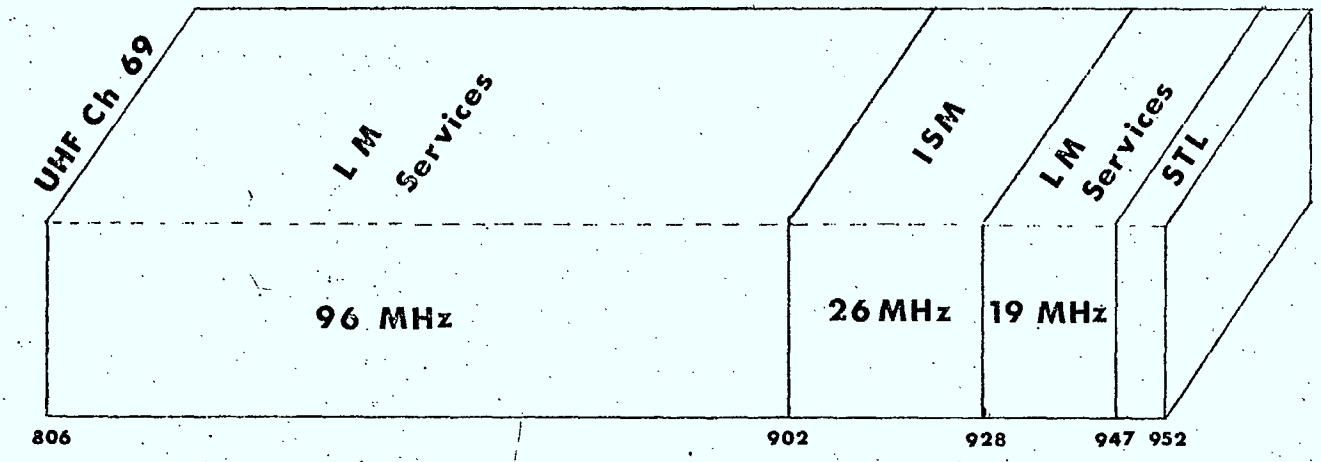
The Second Notice of Inquiry addressed itself more specifically to the question of sub-allocations within the newly allocated spectrum. The FCC requested interested parties to undertake detailed technical and marketing studies.

EVOLUTION OF DOCKET 18262

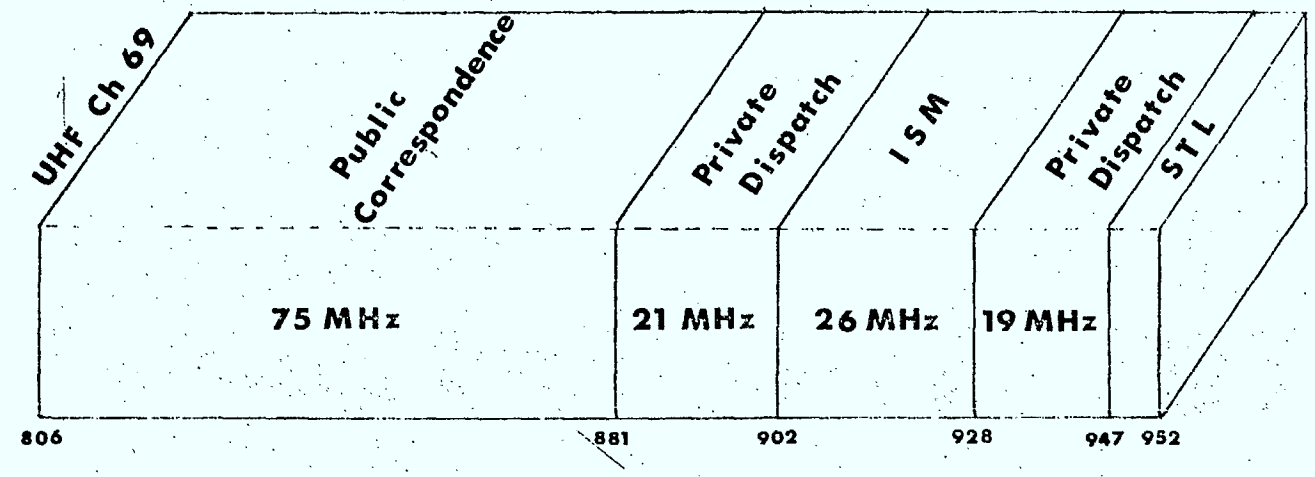
Prior to 1968



Notice of Proposed Rule Making of July 17, 1968



First Report and Order of May 20, 1970



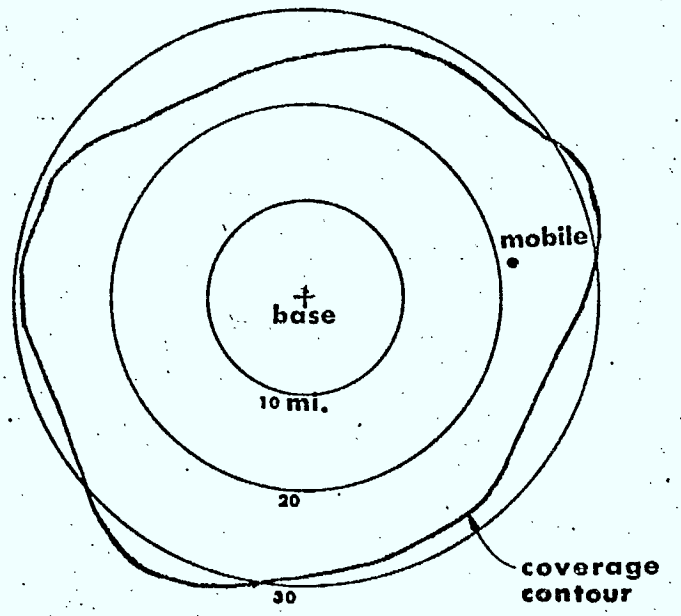
On May 2, 1974, 6 years after proposing the rule making, the Second Order and Report on Docket 18262, sub-allocating the 115 MHz of spectrum to the various services, was finally adopted. (These sub-allocations will be analyzed in a later section).

Two major concerns, AT & T and Motorola, expended substantial resources, time and talent, during the period between 1970 and 1974, to develop efficient cellular systems utilizing new concepts. Before attempting a description of these two competing systems, some of the system concepts used must be fully understood.

CELL CONCEPTS

MALL CELL SYSTEM

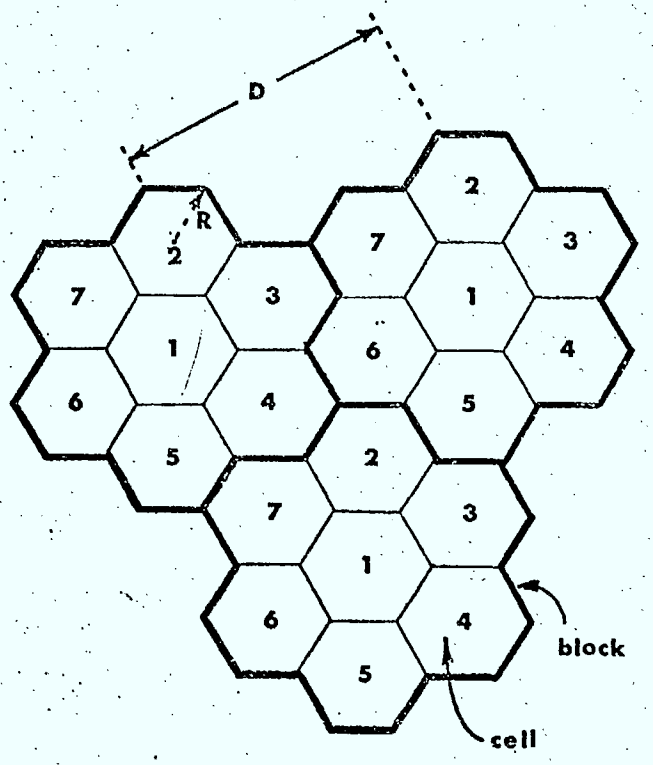
Typically, the approach to mobile radio coverage is to have a high-powered base station on a tall building and radiating omni-directionally to cover the intended service area. This service area is defined, in a statistical manner, as the locus of all points for which there is a good probability (say 90%) that the signal is above some threshold level.



The high-power base station transmitter covers a surface area of roughly 3000 sq. miles. Because of the high power, that same frequency cannot be reused for a distance of ≈ 75 miles, otherwise co-channel interference results.

Landline facilities are used to connect the dispatch center to the base station covering a small cell. The location of the vehicle must always be known so that a conversation can be switched from cell to cell as the vehicle moves. Cells which are separated by less than the minimum allowable co-channel reuse distance must be assigned different channels.

Shown below is a grid of hexagonal cells separated into repeating "basic blocks" consisting, in this example, of seven cells each. Each cell of a given block requires an independent channel set, and the basic block may be repeated as indicated to cover any desired area.



The separation between the center of cells using the same channels is designated D, and the cell radius is designated R. The design of an efficient small cell system requires that the ratio D/R be minimized. A small D will allow the same set of frequencies to be reused a greater number of times in a city and a large R will reduce system costs by requiring fewer base stations to cover the same city. However, the important parameter to the user is the Signal to Interference (S/I) ratio and not D/R.

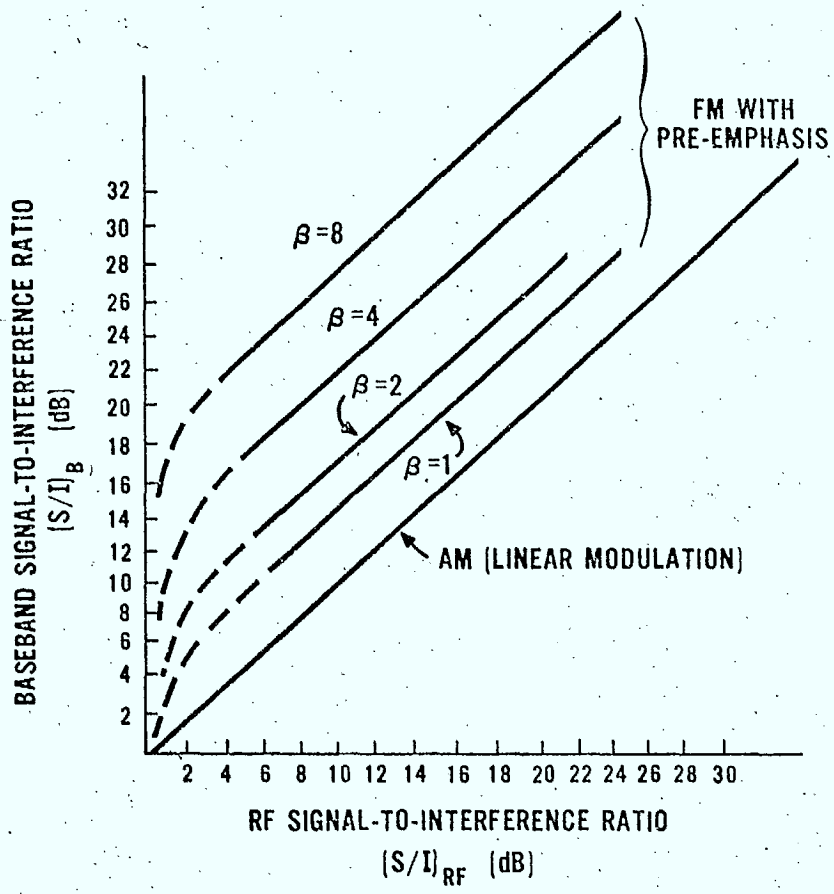
The values of D/R and S/I at the receiver input can be related through the use of a suitable propagation model.

A knowledge of the receiver characteristics permits to relate the S/I at the RF stage and the S/I at baseband frequency which will give an acceptable circuit quality. Circuit quality is determined by subjective evaluations.

FM "Capture Effect" Phenomenon

The "capture" phenomenon refers to the ability of an FM receiver to completely reject all but the strongest of a group of signals which simultaneously impinge upon it.

As shown in the following diagram, this phenomenon depends upon the FM deviation ratio or modulation index of the communications channel.

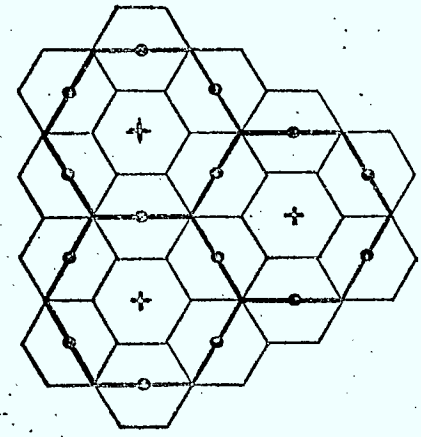


$$\beta = \frac{\text{MAXIMUM FM DEVIATION}}{\text{MAXIMUM BASEBAND FREQUENCY}}$$

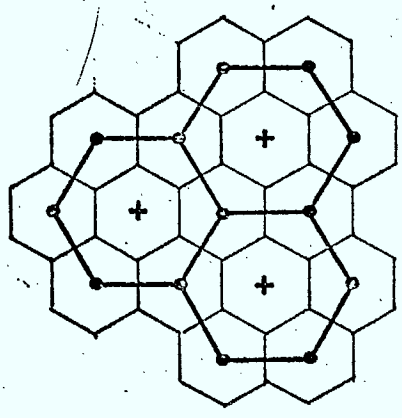
Comparison of AM to Various Bandwidths of FM

Cell Size Reduction

In any given system, mobile user densities will vary from high-density city centers to low-density suburbs, and the best cell size will also vary. System capacity can be increased by adding new base station sites in such a way as to reduce the original cells into much smaller cells. This can be accomplished in the following manner.



4:1 Area Reduction

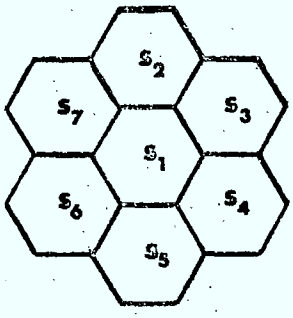


3:1 Area Reduction

+ Original sites
o Added sites

Frequency Assignment

The total number of channels available "C" to the system is divided into "S" separate frequency groups (or sets) corresponding to the number of cells per block. Each group therefore contains N (i.e. C/S) channels. Once again assuming a 7-cell block, we have:



Furthermore, if we assume for the purposes of this example that 770 channels are available, then:

C = 770 channels

S = 7 cells / block

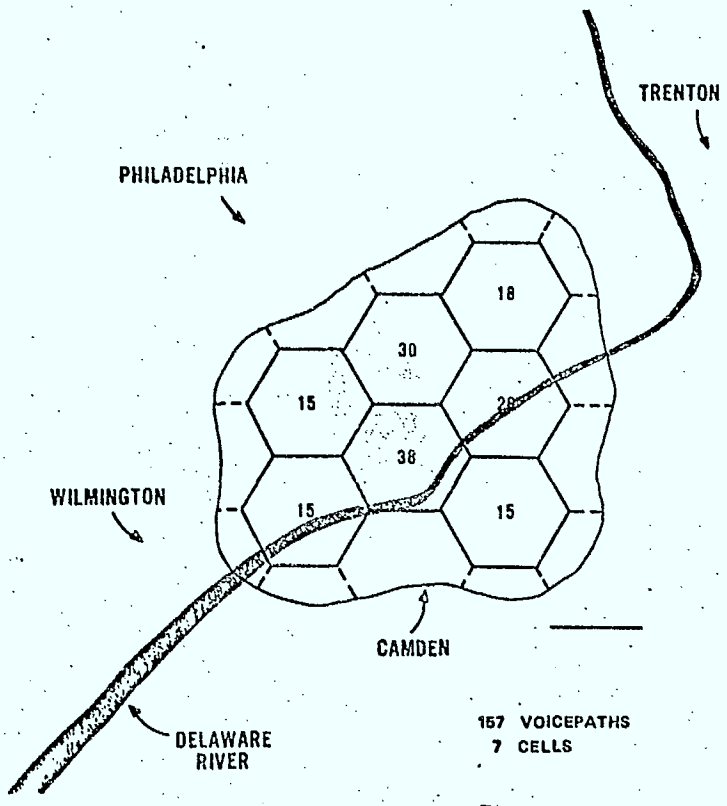
N = 110 channels / cell / block

This means that N (or 110) simultaneous conversations could be handled in a given cell using the frequencies available in that cell. However, since a mobile moves from cell to cell it must be capable of tuning all the frequencies C (or 770) available in the block.

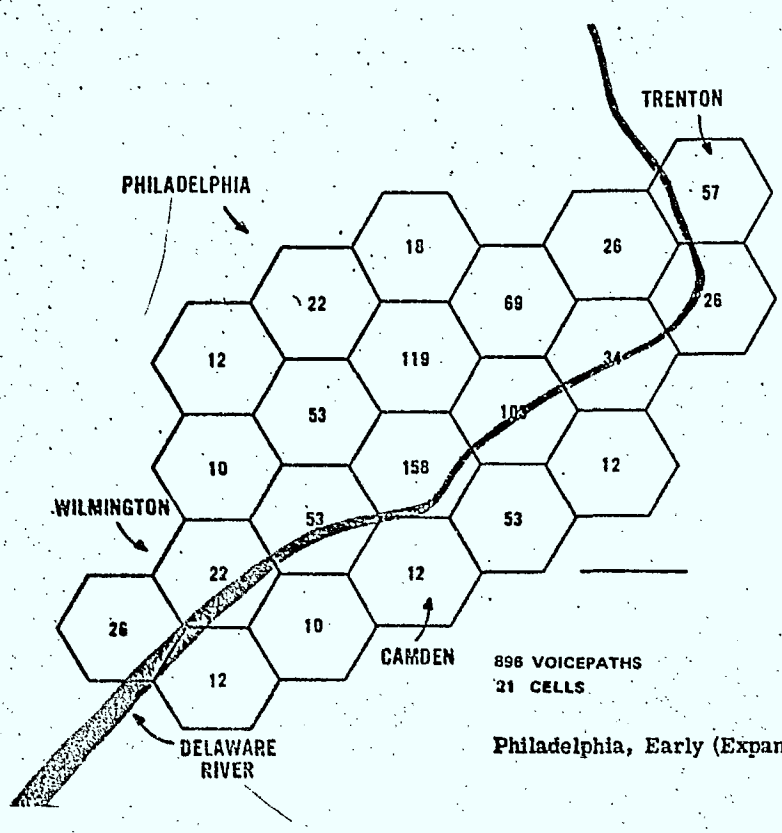
If the traffic intensities offered to all cells were exactly equal, requiring 110 channels in each cell for the specified grade of service, then this fixed channel assignment would be quite satisfactory. However, the traffic fluctuates within each cell and also varies from cell to cell. Therefore the total number of channels in a cell must be tailored to match loads in various cells. This tailoring technique is termed fixed-static borrowing frequency assignment.

If instead of fixing the number of channels in the cells, channel allocations were made on an instant-by-instant basis using knowledge of the exact busy/idle status of all channels, then we would have dynamic assignments.

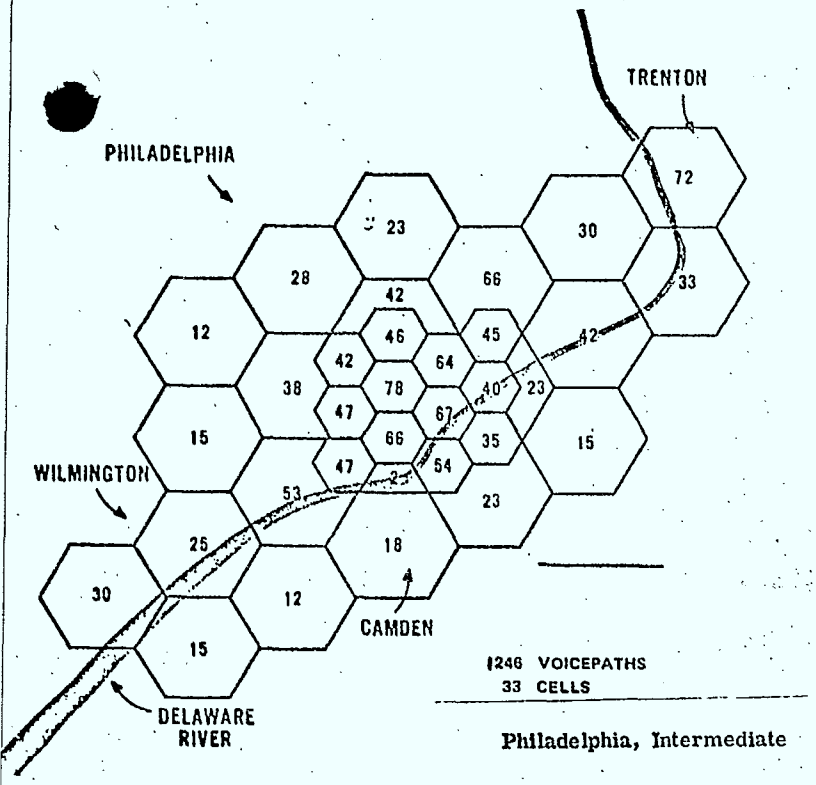
Perhaps the easiest way to visualize the mechanics of channel assignment is to trace the growth of a system through several phases in its development.



Philadelphia, Start-up



Philadelphia, Early (Expanded Area)



Philadelphia, Intermediate

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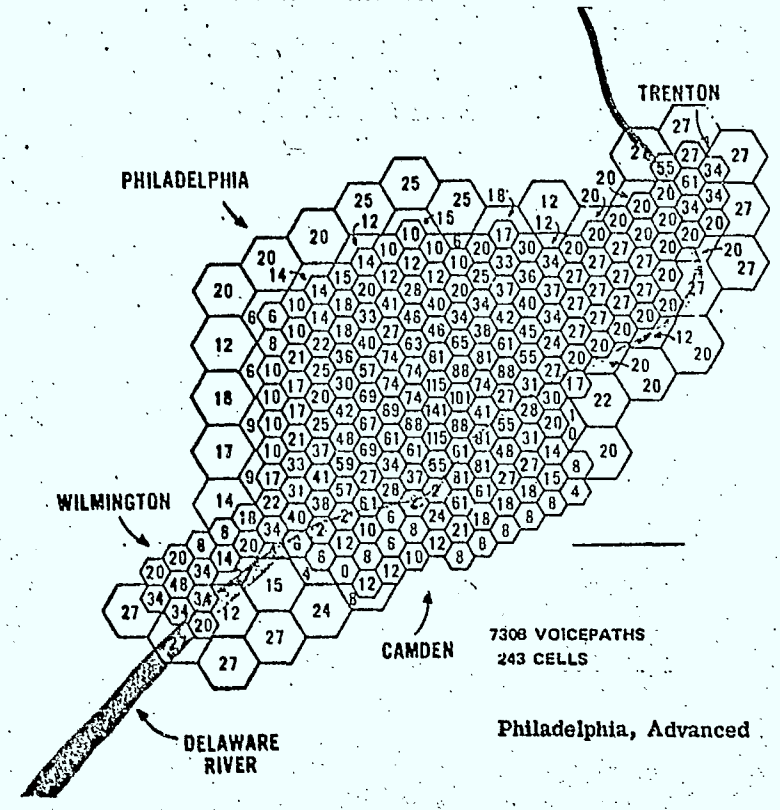


Philadelphia, Advanced

MOTOROLA PROPOSAL

Motorola vigorously rejected the AT & T proposal to provide MTS and Dispatch services on the same system. Motorola argued that AT & T's entry into private dispatch would have serious anticompetitive and other monopolistic consequences.

Motorola advanced the following reasons as to why the FCC should not increase the AT & T spectrum allocation from the present 1.2 MHz to 75 MHz for the development of a hybrid mobile telephone/ dispatch system.

1. System Vulnerability

   The AT & T system is susceptible to service disruption caused by equipment failure. A breakdown at the control office (central exchange, computer) quickly renders the entire system inoperative. This is not a desirable feature for police, fire and other emergency services.

2. Message Lengths

   The operation of a private LM system is characterized by brief, highly disciplined communications exchanges. The average duration of these transmissions is 10 - 20 seconds.

   The car telephone subscriber and those to whom he is talking regard the radio usage as a logical extension of the home or

office landline telephone. The duration of such communications is between 180 and 240 seconds. This will obviously increase the average message length of a mixed MTS - dispatch system, leading to longer waiting times thus reducing efficiency for dispatch purposes.

3. Hand-Offs

The difference of message length has yet another impact. For the relatively long-talking car telephone user, a reliable vehicle location system is a must. There is a good probability that the vehicle will cross from one cell to another during a conversation. This necessitates a complex logic mechanism to accomplish hand-offs, thus raising overall system costs.

The probability that a dispatch user crosses a cell boundary is much smaller and therefore a complex vehicle location is not required.

4. Fleet Calls vs Person-to-Person Calls

The car telephone user has the need to contact and be contacted randomly by anyone who has access to the wireline system. The communications are of an individual nature.

A private dispatch radio system is an integral tool of management; transmissions are designed to impact on all members of the system. Examples are: i) taxi dispatcher announcing the existence of a potential fare to all cabs, ii) the familiar "calling all cars"

emanating from police headquarters. This would lead to a discernible decline in spectrum efficiency since a cell system utilizing duplex operation requires a separate channel for each dispatcher-mobile call

5. Portable Two-Way Radios

There is no provision in AT & T's MTS- dispatch system for personal two-way radios. Yet there is a necessity to be in contact with the policeman on the beat, the fireman in the building,...

To correct this situation Motorola has developed the Dyna-T-A-C system for portables.

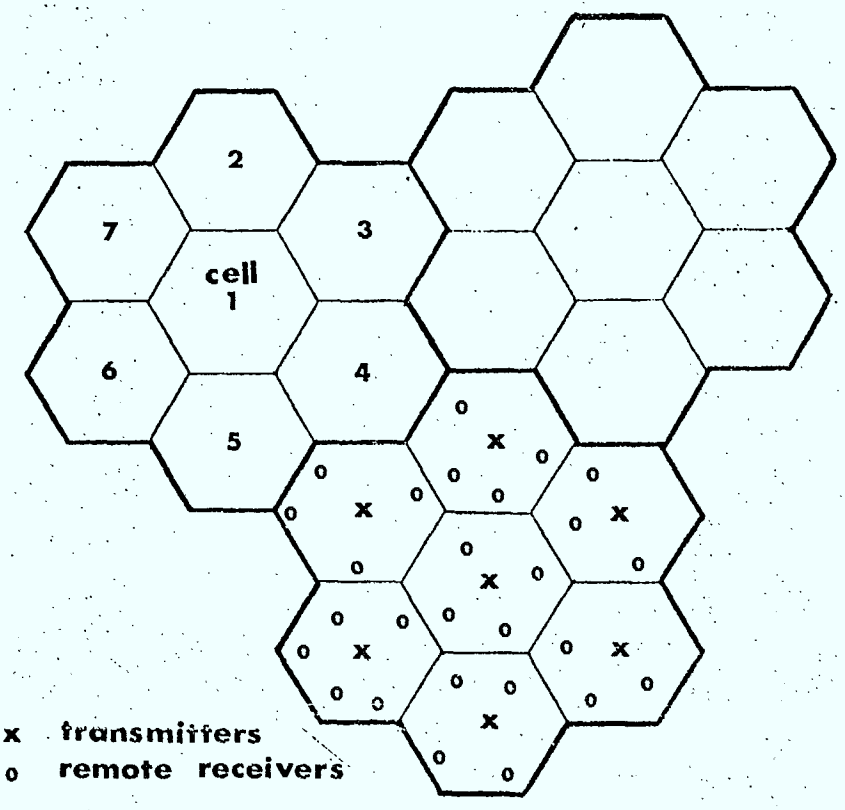
MOTOROLA SYSTEMS

1. MOBILE TELEPHONE SYSTEM (MTS)

Motorola proposes a cellular system requiring 19 MHz of spectrum. It is predicted that, in a given area, such a system could eventually serve 178,500 public telephone mobile subscribers by the year 2000.

System description

- 7 cell block (cells need not be symmetrical)
- channels are spaced 25 kHz apart
- FM deviation is 5 kHz
- 19 MHz gives 380 duplex channels.



- Vehicle Location is required
- Base Stn Transmitter power is 5 Watts

2. PORTABLE RADIOTELEPHONE SYSTEM

(Dynatac for Dynamic Adaptive Total Area Coverage)

The system is identical to the Mobile Telephone System.

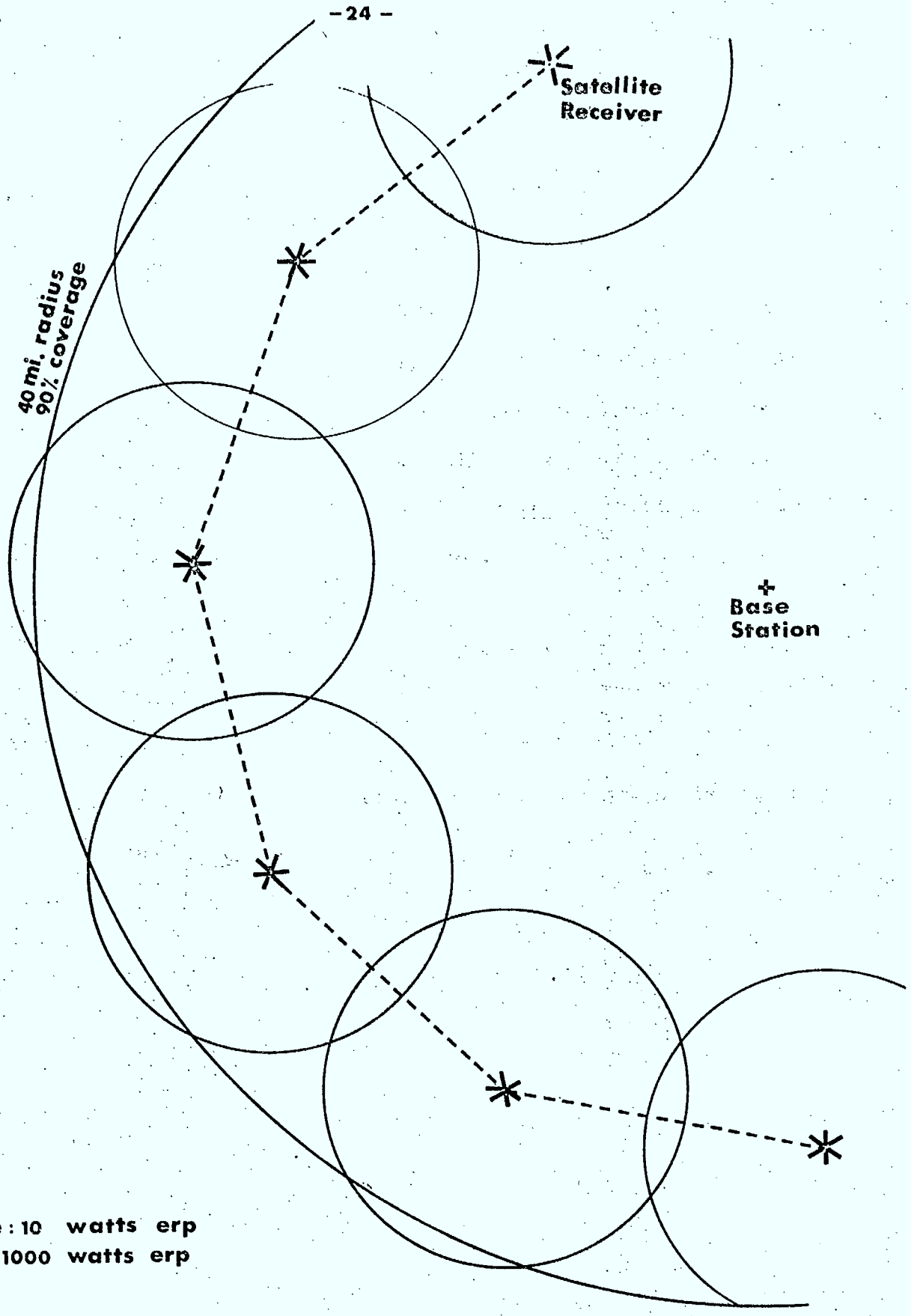
Note: When this system was proposed Motorola recognized that their 25 kHz wide channels were not fully adequate for a 7 cell system. Therefore to afford more protection to co-channel interference it was proposed to offset frequencies in adjacent blocks by 1/3. This is known as tertiary offset.

3. MULTI-USER SHARED PRIVATE DISPATCH SYSTEM

(Also known as "3C" for Central Coverage Communications)

System features

- 20 trunked channels in 1 MHz
- Wide area coverage
- Central location for base transmitters
- Multiple outlying receiver sites
- All call for each user fleet
- Low powered mobiles.



mobile : 10 watts erp
base : 1000 watts erp

3C SYSTEM

Also the use of the 900 MHz band is not well suited for aeronautical services which generally require a high degree of international standardization. The use of these frequencies for mobile services in the U.S. will be in derogation of the ITU Region II allocations and coordination of aeronautical service with neighboring countries would be difficult if not impossible.

III. Frequency Allocations to Conventional and Trunked LM Systems

An allocation of 30 MHz of spectrum for conventional and trunked system was made available with additional bands so placed as to be readily accessible for future growth if needed.

It is expected that systems will be primarily for fleet dispatch operations.

IV. Provisions for ISM Devices

General Electric Company claims that a reduction of 50 MHz to 26 MHz will make it impossible to continue manufacturing economical microwave ovens for the band in question. It argues that 38 MHz is needed to make an oven which is competitively priced and capable of cooking all types of foods properly.

Since it will be some time (10 - 15 years) before the full LM allocation will be required, an interim provision can be made for continued use of wide band ISM.

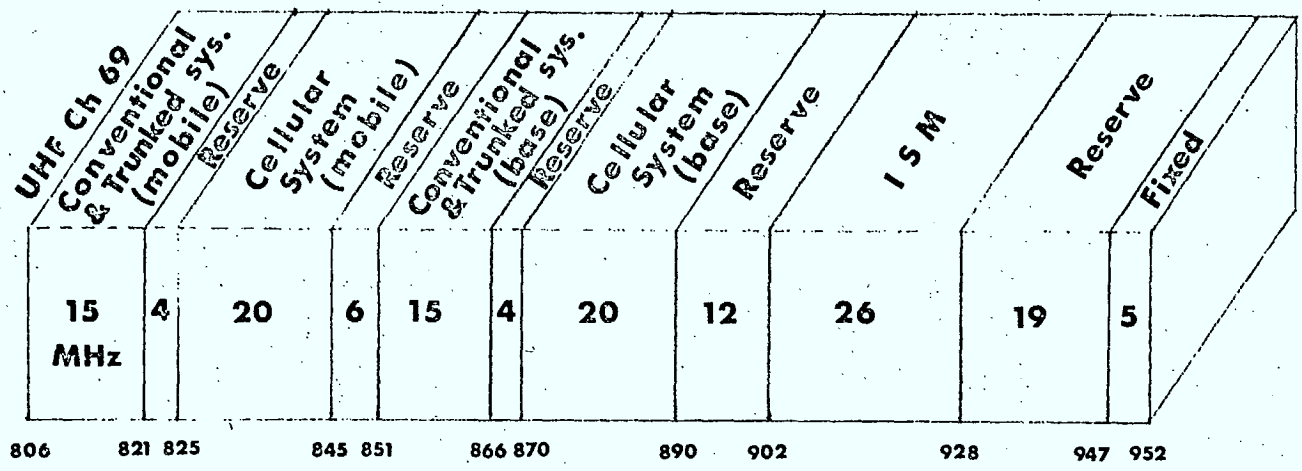
The FCC decided to establish a guard band of 12 MHz wide immediately above the regular ISM provision so that the total spectrum available for microwave ovens would be 38 MHz. This guard band would carry a time limitation of 5 years after which the band would revert exclusively to LM. This will permit the oven industry to develop spectrally efficient devices which can meet the narrower bandwidth.

V. Treaty Considerations

Under present international obligations, LM operation in the 900 MHz band is in derogation of the ITU allocation table for Region 2. Such derogations are permitted by the International Radio Regs only if protection is given to assignments operating in accordance with the ITU allocation table and interference from such operations is accepted.

The obligation to protect both Canadian and Mexican TV assignments between 806 and 890 MHz will mean that the assignment of some types of LM operations will be impaired close to border areas. This is especially true in Detroit and Buffalo, where even low-powered mobile units might cause interference in certain nearby Canadian UHF-TV coverage areas.

Second Report and Order of May 2, 1974



Channels for Cellular Systems are spaced 40 kHz apart.

Channels for Conventional and Trunked Systems are spaced 25 kHz apart.

FCC Policy Relating to Cellular Systems

- Only wireline carriers will be licensed to operate cellular system. This is because wireline carriers are the only organizations which have demonstrated that they possess the resources and expertise necessary to establish systems requiring extensive interconnection with the wireline telephone system and having nationwide compatibility.

- In order to operate a cellular LM system a wireline company will establish a wholly separate operating company with separate books of account, offices and personnel.

- The wireline companies will not be permitted, directly or indirectly, to manufacture, provide or maintain mobile equipment.

- Cellular systems will not be allowed to offer dispatcher-originated communications service with "fleet call" capability.

CANADIAN REACTION

It is inevitable that some of the system concepts and technology developed in the U.S., for the 900 MHz part of the spectrum, will spill over into Canada. Also, because of international agreements, assignments of 900 MHz frequencies in U.S. cities close to the Canadian border will require DOC's blessing. We must, therefore, keep a close watch on what is happening in the U.S. and constantly update our knowledge of the situation.

In 1970, DOC responded to the U.S. activities by:

i) undertaking technical as well as socio-economic studies.

ii) holding discussions and fact finding meetings with the FCC

iii) requesting the CRTPB to study and report on the Canadian situation in the frequency band 470 - 960 MHz.

The various Land Mobile studies indicated that in the heavily populated Canadian cities, a state of congestion will not be reached until the 1980's.

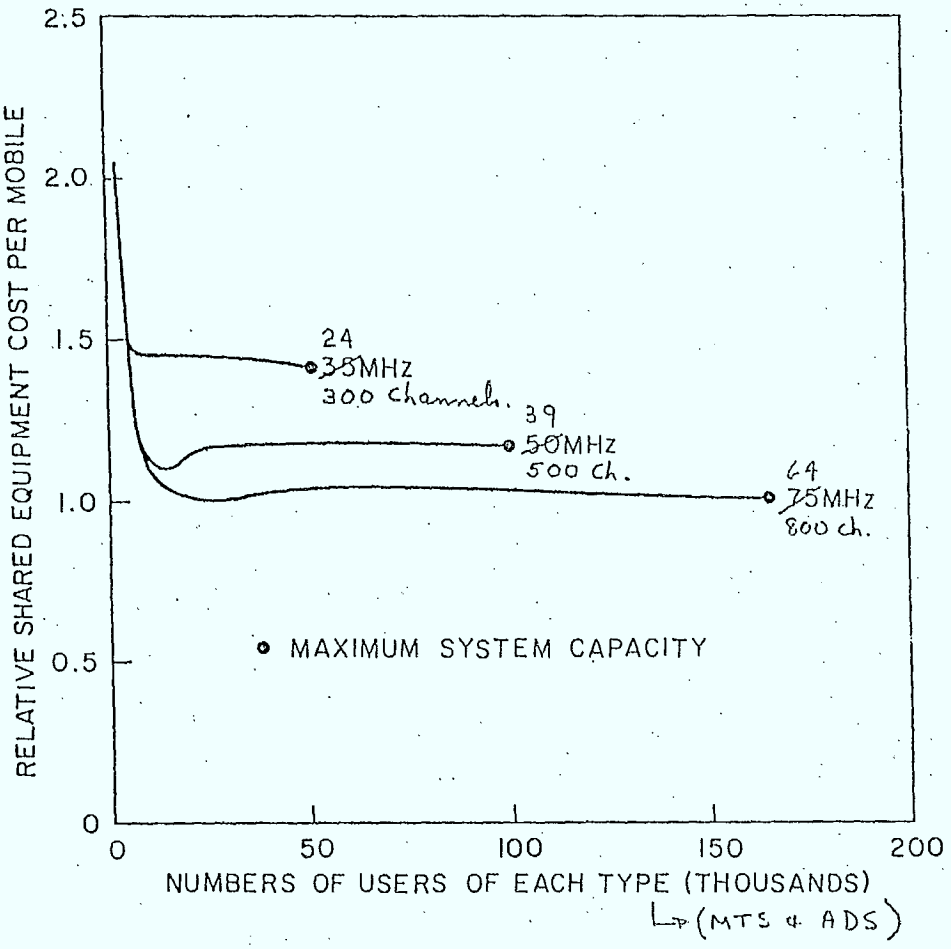
The CRTPB formed the "Ad Hoc Committee on the Band 470 - 960 MHz." A Task Force on UHF-TV Taboos was also set up to provide technical inputs to this Committee. In June 1974, the CRTPB made its final recommendations to DOC. Briefly stated these are:

- that spectrum sharing be accepted in Canada within the band occupied by TV channels 14 through 20 inclusive (470 - 512 MHz), and that realistic rules for such sharing between TV and Land Fixed and Mobile services be developed.
- that the upper part of the present UHF-TV band, 806 - 890 MHz (channels 70 - 83), be reallocated; that the bands 806 - 902 and 928 - 960 MHz be allocated for Land Mobile and Point-to-Point services.

There is no doubt that, some time in the future, congestion will develop in the present Land Mobile bands. For the present, however, our needs are not the same as the U.S. Nevertheless, efficient spectrum planning dictates that a decision on the course of action to follow in Canada be made at an early stage.

	AT & T	MOTOROLA			
1) Type of service	MTS & ADS	MTS only	Dynatac (Portables)	Dispatch "3C"	Conventional
2) Spectrum requested	64 MHz	19 MHz	19 MHz	1 MHz	----
3) Channel Width	40 kHz	25 kHz (T.O)	25 kHz (T.O)	25 kHz	25 kHz
4) No. of duplex channels	800	380	380	20	----
5) Channel loading	40 users/ch	25 users/ch.	25 users/ch.	100 users/ch.	----
6) Vehicle loaction	Yes	Yes	Yes	"Voting"	No
7) Computer controlled	Yes	Yes	Yes	Yes	No
8) City & coverage area	Philadelphia ≈ 1300 sq. mi	Chicago ≈2900 sq. mi	New York	Chicago	____
9) Maximum capacity	≈300,000 total users	≈180,000 users	≈180,000 users	2000 users	
10) Spectrum efficiency	1.8 duplex ch/MHz/ cell or 72 users/ MHz/cell	2.9 duplex Ch/ MHz/cell or 72 users/ MHz/cell	← Same ← Same		
11) Costs	$410 per ADS mobile user $560 per MTS mobile user			$300/mobile user	15% higher than 450 MHz band.
	$950 per mobile unit ADS $1360/mobile MTS $1510/mobile			$750/"3C mobile unit $1050/mobile	Actual cost depends on options
	≈$59/Month estimated by Motorola	≈$90 / month	≈$90/month		

AT & T



Sensitivity of Cost and Capacity to Available Spectrum