Signal Capacity Modeling for Shared Radio Systems Planning

March 4, 2004

Gary Patrick, NTIA/SEAD
Bob Matheson, NTIA/ITS
Charlie Hoffman, NTIA/PSD

Overview

- **Background**

- **Federal LMR Studies**
- **Phase I - Analyze Current Systems**
- **Signal Capacity Model**
- **Phase 1 Results**

- **Phase 2: Improved Alternative Systems**
- **Potential Advantages of Shared Systems**
- **Some Unknowns**

- **Summary**

Background

- Increased pressure from Private Sector for government spectrum.
- The Federal Government's efficient use of the spectrum has often been questioned.
- What improvements could be made in Federal use of the Spectrum?
- Concentrate on spectrum effectiveness as opposed to technical spectrum efficiency.

A Problem of Perception

Perception: Public Safety (Federal or non-Federal) is generally an inefficient user of spectrum.

– Most Federal mobile radio use is for public safety functions—therefore, inherently difficult to make efficient.

–This project (aimed at Federal users) is actually studying a general Public Safety problem.

–PS requires high reliability and availability, with channels whose traffic loads change drastically with planned or unplanned events.

–Poor efficiency in non-Federal PS bands is major source of requests for additional transfer of Federal spectrum.

Objective

- To conduct a multi-phase study of the current and future use of the Federal land mobile spectrum (162-174 MHz) in the Washington, DC area.
- Based on this use, determine the technical improvements or changes via technology, spectrum management practices, policies, and standards to increase effective and efficient use of the spectrum.

Step 1: Federal LMR Studies

- Intensive study of Federal LMR functionality in representative areas (DC, NYC, rural).
- Reconstruct existing capabilities with modern shared, trunked infrastructure alternatives.
- Compare existing with new alternatives: cost, frequencies, coverage, capabilities, etc.
- Consider, P25, narrow-banding, SAFECOM, IWN, Dept of Homeland Security, etc.
- Decide whether to implement any alternatives

Analyze Current Systems

- Analyze the Federal land mobile radio service in the 162-174 MHz band in the Washington, DC area (100-mi radius).
  - Frequency assignment data in the Government Master File (GMF), including transmitter power, antenna location, frequency, bandwidth, user, etc.
  - The nature of mission requirements and detailed network structures for each Federal agency.
  - Interviews with Agency representatives to understand and confirm.

Signal Capacity Model

- Signal Capacity (SC) model counts the number of independent mobile radio signals that could be received at each point on map.
- Compute transmitter coverage areas from GMF data.
- Add SC function code to each GMF assignment to indicate how transmitters add together to give SC maps (different types of transmitters may or may not transmit independent signals)
- SC maps for individual agency networks, for entire agencies, and for large groupings of Federal agencies
- SC maps are needed to show how many radio signals must be furnished by future radio systems to duplicate the performance of current Federal radio systems.

Signal Capacity

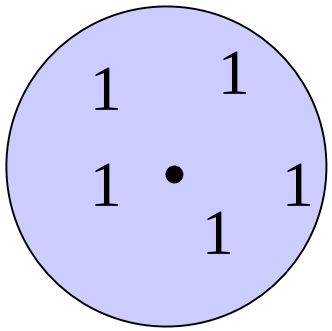
- **Signal capacity –** A method of summarizing the amount of service delivered to a mobile user.

- **Peak SC** is calculated by counting the number of independent mobile voice signals that can be received by a user at a given location. Summarize in an SC coverage map. (Note: a signal is a signal is a signal.)

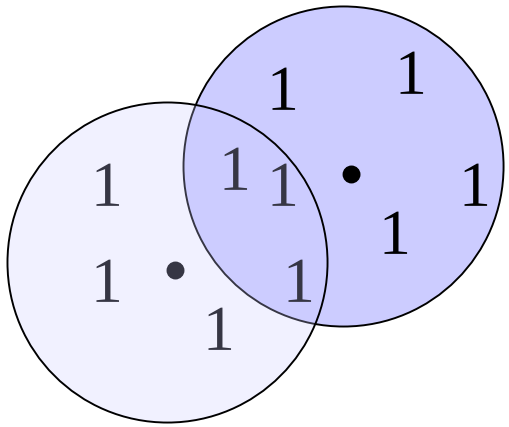
- Use terrain-based Longley-Rice propagation model to calculate coverage based on transmitter data from GMF and coverage equal to 10 uV/m, 90% of locations, 50% of time.

Peak SC Examples

Single Xmtr



Two Xmtrs

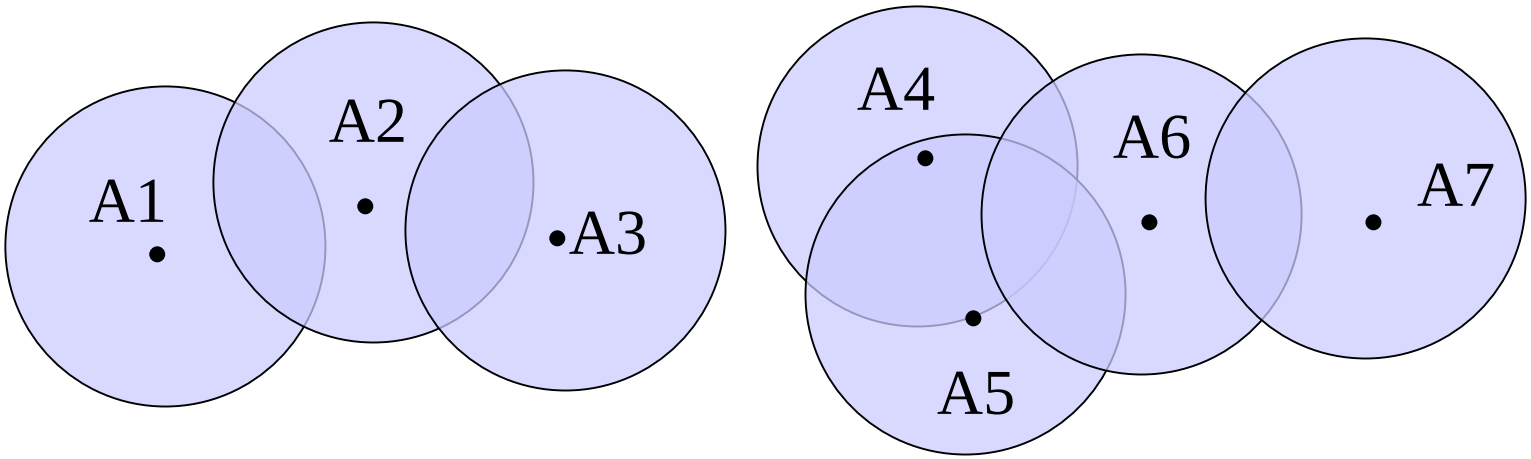


Does Peak SC add? Depends on whether two signals are independent.

Trunked – yes, different frequencies – yes.

Simulcast – no, same freq – no, same message – no.

Peak - Multi-site Repeaters

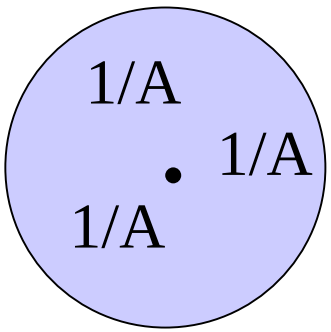


- Consider a chain of mountaintop repeaters operating at the same frequencies.

- Peak SC cannot add in overlap areas, since adjacent signals will interfere. But, don't know in advance whether coverages overlap.

Average SC Model

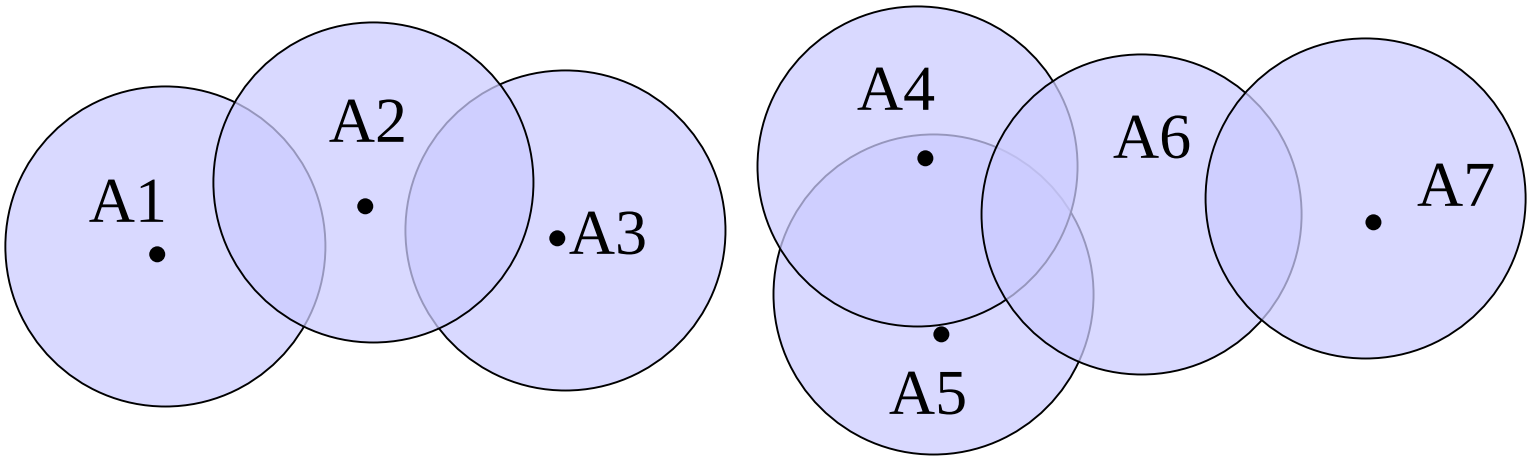
• Many traffic models begin with “users”/ sq. mi, and size base station capacity requirement proportional to sq. mi. of base station coverage.



- The Average SC model shows what average density of users are supported. Area = A. ASC density x total coverage area = 1 independent user, 100% of time.

- Average SC assumes users evenly spread out. ASC is needed to allow traffic to be scaled with coverage area of cells.

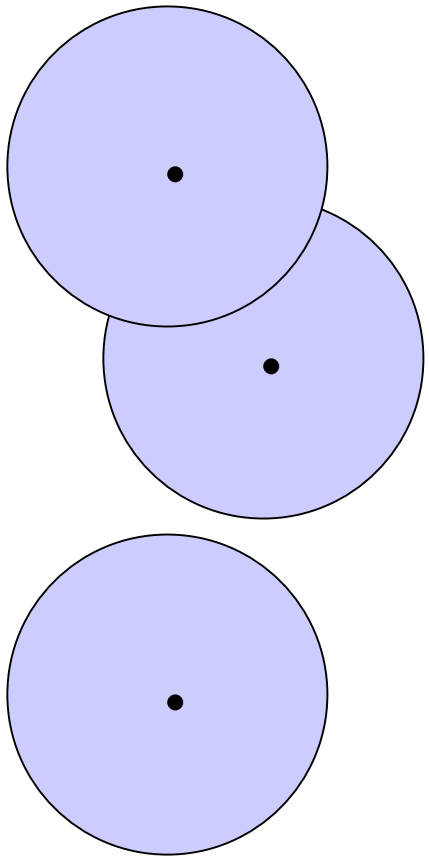
Average - Multi-site Repeaters



- Consider a chain of mountaintop repeaters operating at the same frequencies.
- Note: A1, A3, A4, A7 could all operate simultaneously (since non-overlapping).

Average SC: $1/A_N$ in non-overlapped areas, average the ASC values in overlapped areas.

SC Network Models



Given a GMF transmitter, how do you know whether its coverage is independent of other coverages?

Answer: You don't.

Network – all related xmtrs.

Function code - What to do with them

Coordination with Federal Agencies

- Almost 2000 Federal Licenses in 162-174 MHz Band in GMF within 100-mi radius.

- Examined every GMF license and assigned suitable Function codes and Network designations.

- Checked with Agency frequency managers to verify proper understanding of function and network for each GMF assignment.

Summary of Federal Licenses

Function	Description	# of Assignments
F = 3	Individual Base station transmitter	247
F = 6	Trunked network	5
F = 7	Single-message repeater network	274
F = 8	Multiple-message repeater network	220
F = 9	Mobile-only user net	120
	Total included = 866	
F = 20	Obsoleted link	84
F = 21	Dedicated link	333
F = 22	Receiver	418
F = 23	Receiver-only station	180
F = 25	Low power (10 mW or less)	28
F = 26	Mobile-only (replaced by new system)	36
	Total not included = 1079	

Computation of SC Maps

- Based on Function and Network Codes, GMF License entries were analyzed.

- Peak and Average signal capacity maps for each independent network (one or more licenses)

- Network maps combined into Agency maps (by adding Peak and Average SC values, respectively, on a point-by-point basis.

- Agency maps combined to give maps for All-Agency and other groupings.

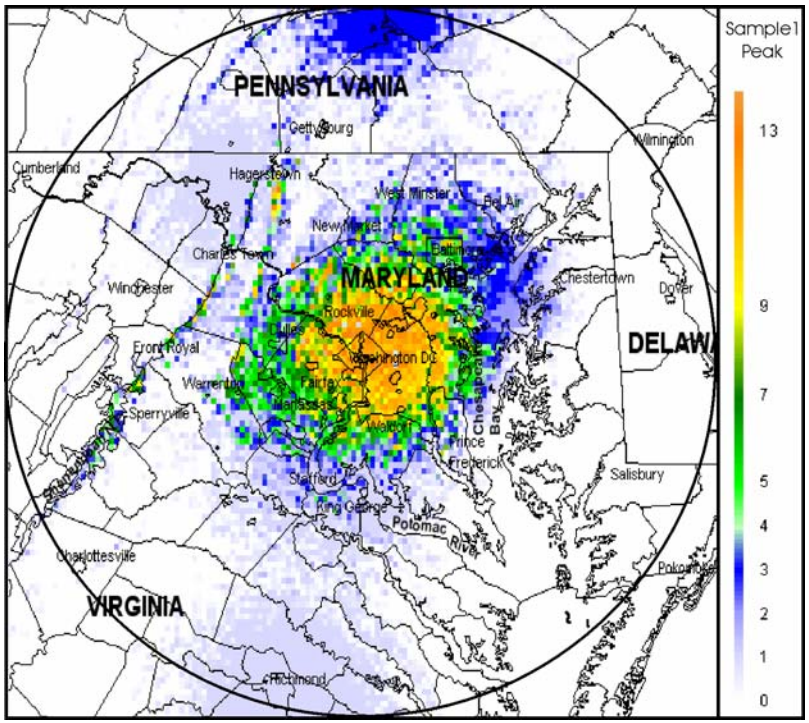
Phase I Results

- Give a snapshot of what radio services exist, with Peak and Average Signal Capacity maps for Federal agencies in Washington, DC area.

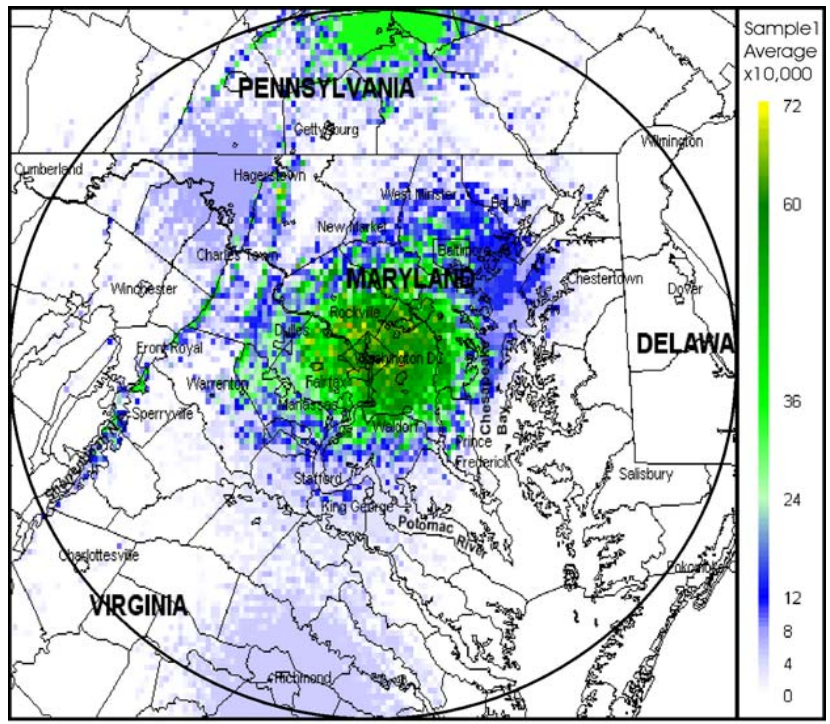
- Will give a quantitative basis for comparison with alternative versions of future system designs.

- Agency consultations and preliminary analysis has provided NTIA with improved understanding of agency radio needs.

Sample "Small Agency" Outputs

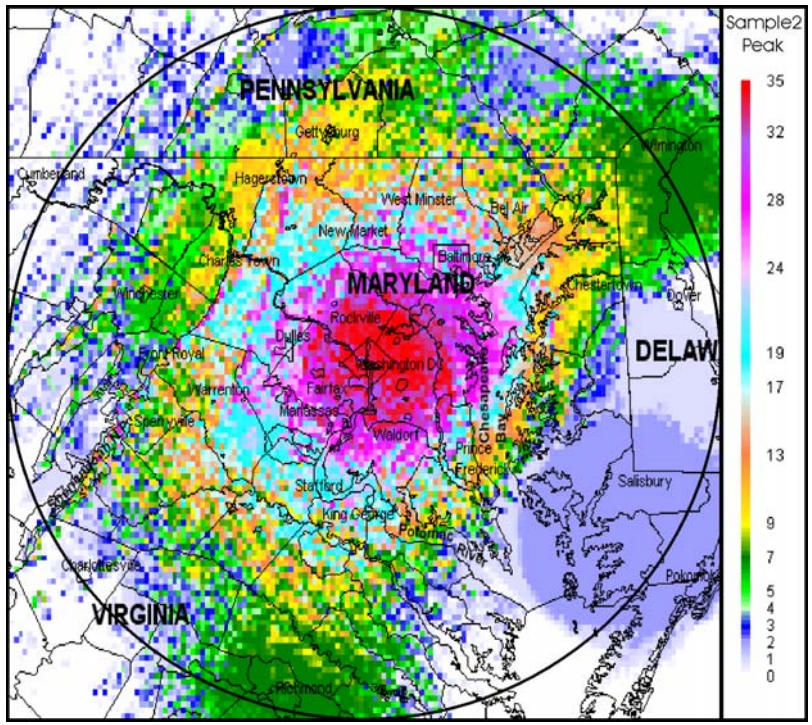


Sample Peak

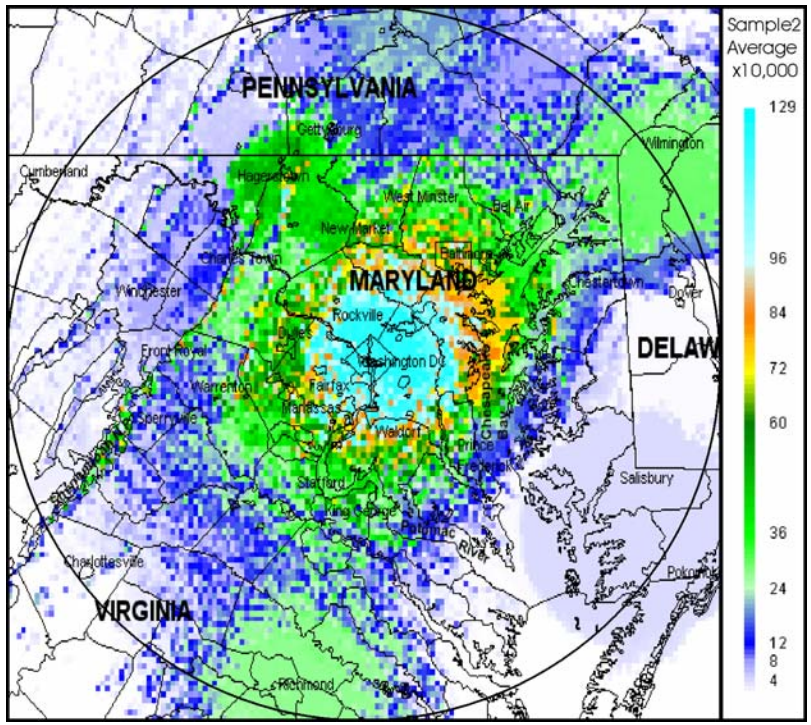


Sample Average

Sample "Large" Agency Output

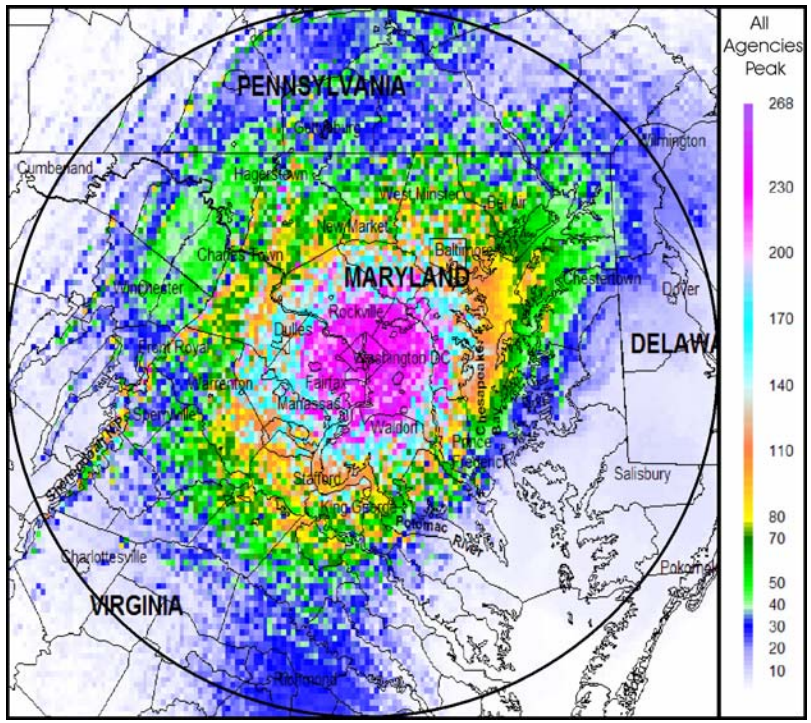


Sample Peak

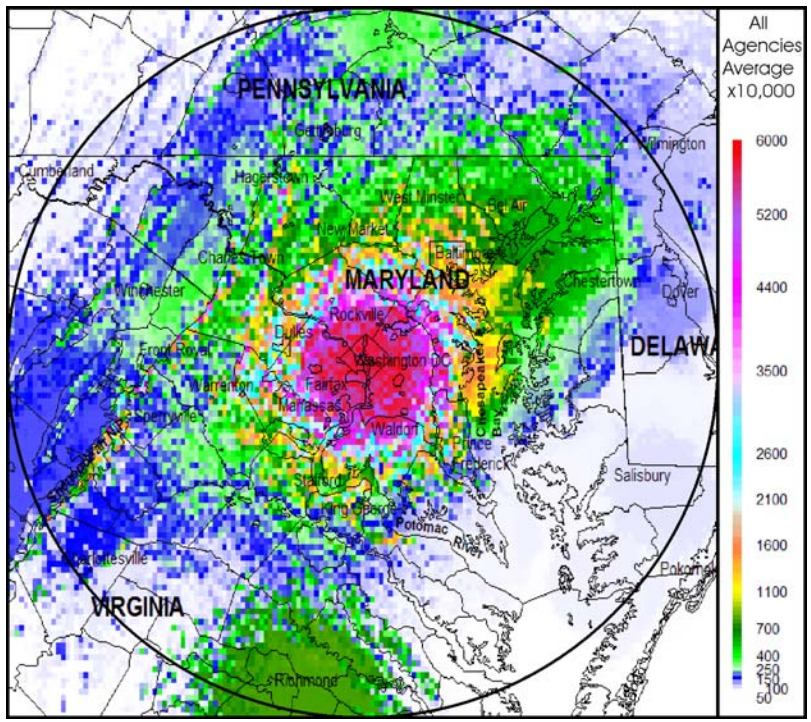


Sample Average

Sample All-Federal Output



Sample Peak



Sample Average

Phase II – Improved Alternative Systems

- Use SC maps as coverage/capacity requirement for future alternative systems.
- Design multiple alternative systems, using various technology and agency participation assumptions.
- Estimate costs, coverage, frequencies needed, capabilities, etc. for various alternative systems.
- Determine improvements in spectrum effectiveness for land mobile networks.
- Decide which, if any, alternative systems to recommend for further study.

Potential Advantages of Shared Systems

- More features (text messages, encryption, priorities, flexible talk groups, database access, graphics, etc.).
- Expanded geographical coverage.
- Interoperability and instant reorganization for emergencies.
- Lower costs from major economies of scale.
- Fewer needed frequencies and frequency bands.

Some Unknowns

- Funding, costs, timetables.
- Relationship to Homeland Security, SAFECOM, etc.
- Suitable governing agency and rules.
- Agency reactions - independence lost?
- Functionality of P25 and large shared systems.

Summary

- **5-Phase program to determine more effective use of Federal Spectrum.**
  - Analyze current Federal usage in DC/Baltimore Area.
  - Develop designs for future comparable shared systems.
  - Spectrum distribution and policy improvements.
  - Technical standards for Federal LMR Networks.
  - Recommendations and Implementation.
- **Phase-1 studies completed.**
- **SCAP Signal Capacity Maps near completion.**
- **Phase-1 report planning early 2004 publication.**

QUESTIONS?

Spectrum Efficiency Team:

Don Speights – Chief,
Public Safety Division
202-482-1726
wspeights@ntia.doc.gov

Gary Patrick, Task Lead
202-482-9132
gpatrick@ntia.doc.gov

Bob Matheson, ITS Boulder
303-497-3293
matheson@its.bldrdoc.gov

Charlie Hoffman, Public Safety Division
202-482-3456
choffman@ntia.doc.gov