Title Page

Spectrum Management Perspectives on Wireless

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Principles

**** Solely the author's opinions; do not necessarily reflect official policies. ****

- ☆ **Spectrum will be available and useful.**
- ☆ **New wireless systems will be different from traditional systems.**
- ☆ **Various frequency bands provide various property rights.**
- ☆ **Future competition will be genuine and intense.**
- ☆ **Systems will be larger, more complex, more expensive**

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Enough Spectrum?

Can we possibly find spectrum for all of the proposed new systems?

- ☆ Rapidly multiplying demand for spectrum-based services.
- ☆ Everyone wants large amounts of (free) spectrum.

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- ☆ Spectrum capacity is highly elastic and expanding rapidly
- ☆ Continuous historical trend to use higher frequency bands
- ☆ A glut of new spectrum – spectrum costs going down

Spectrum capacity

Spectrum capacity is the amount of communications that can be carried.

- ☆ Capacity = investment   technology
  (An empty band has "zero" capacity)

- ☆ Factors increasing capacity:

  Optical fiber band reclamation 1.2
  Federal/Military band conversion 1.1
  Availability of higher frequencies 5
  Frequency re-use (short-range systems) . 25
  Digital compression (voice, video) 3

  Total increase in spectrum capacity 495

- ☆ Trade-off between spectrum use vs. technology/investment

Elastic Spectrum Capacity

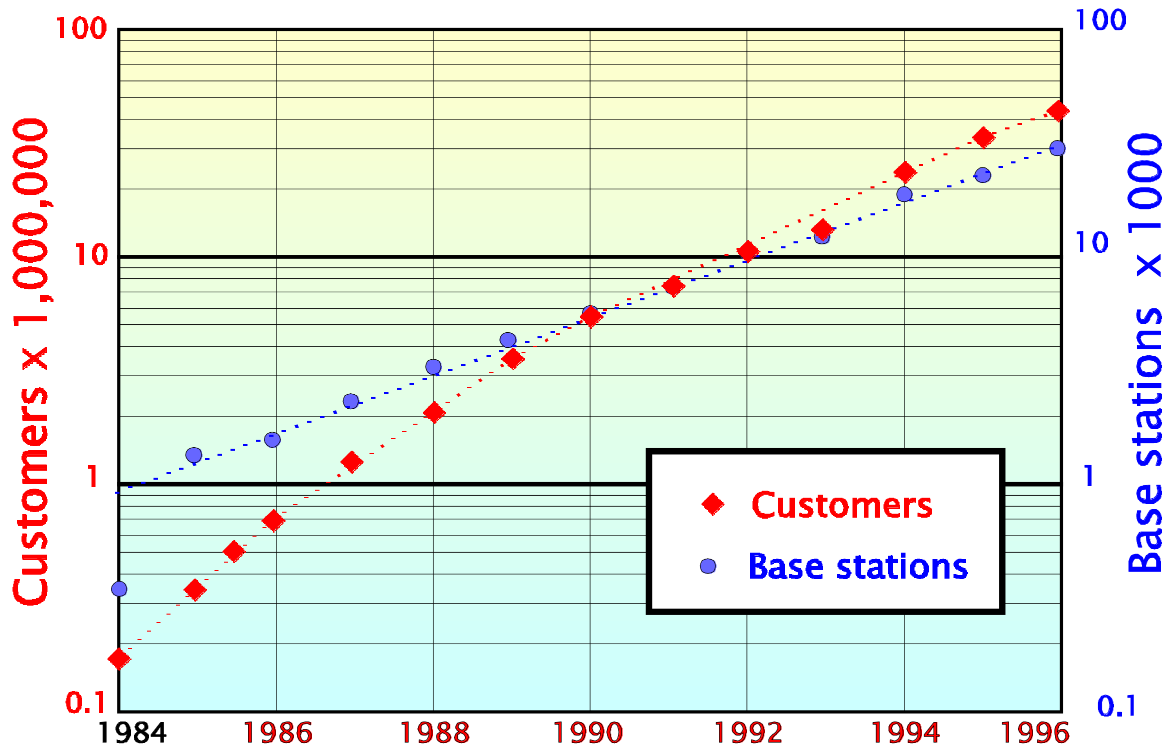
☆ Cellular telephone industry has used many techniques to fit more customers into a limited frequency band

☆ More, smaller sites. Reverse channel power control on portable units.

☆ Segmentation using directional antennas.

☆ 1400 users per antenna site.

U.S. Cellular telephone Industry

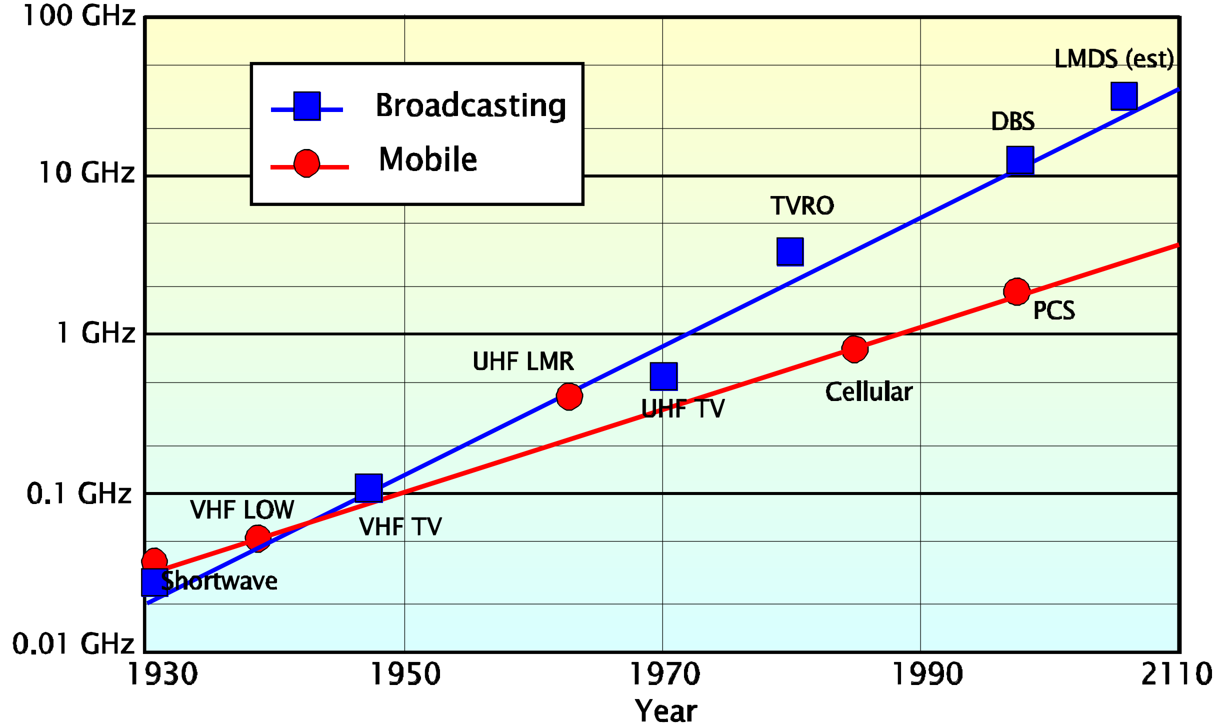


Historical frequency trend

☆ Maximum frequency of usefulness usually limited by electronics technology.

☆ GaAs and Si-Ge processes continually improving, but near 50-75 GHz now.

☆ Historical trend toward continually higher frequencies.



New services versus year of commercialization

Decreased Spectrum Cost

Economics: Cost of spectrum is most realistic measure of scarcity.

- ☆ Recent auctions give first real data on spectrum value.
- ☆ Narrowband and wideband PCS higher-than-expected prices.
- ☆ Recent auctions brought lower-than-expected prices.
  - 40% of C-block returned for re-auction – paid too much
  - WCS spectrum (2.3 GHz) brought 1% of expected value
  - 4.6 GHz band withdrawn from auction–no buyer interest
- ☆ Too much spectrum chasing too few buyers

New System Paradigms

New wireless systems technically different from traditional radio

- ✰ Provide access, not transport (Fiber provides transport)
- ✰ Higher frequencies. Already 30 GHz, and counting.....
- ✰ Digital convergence - <u>everything</u> is just “ones” and “zeroes”.
- ✰ Smart systems, complex, dense infrastructure

High frequency Path Loss

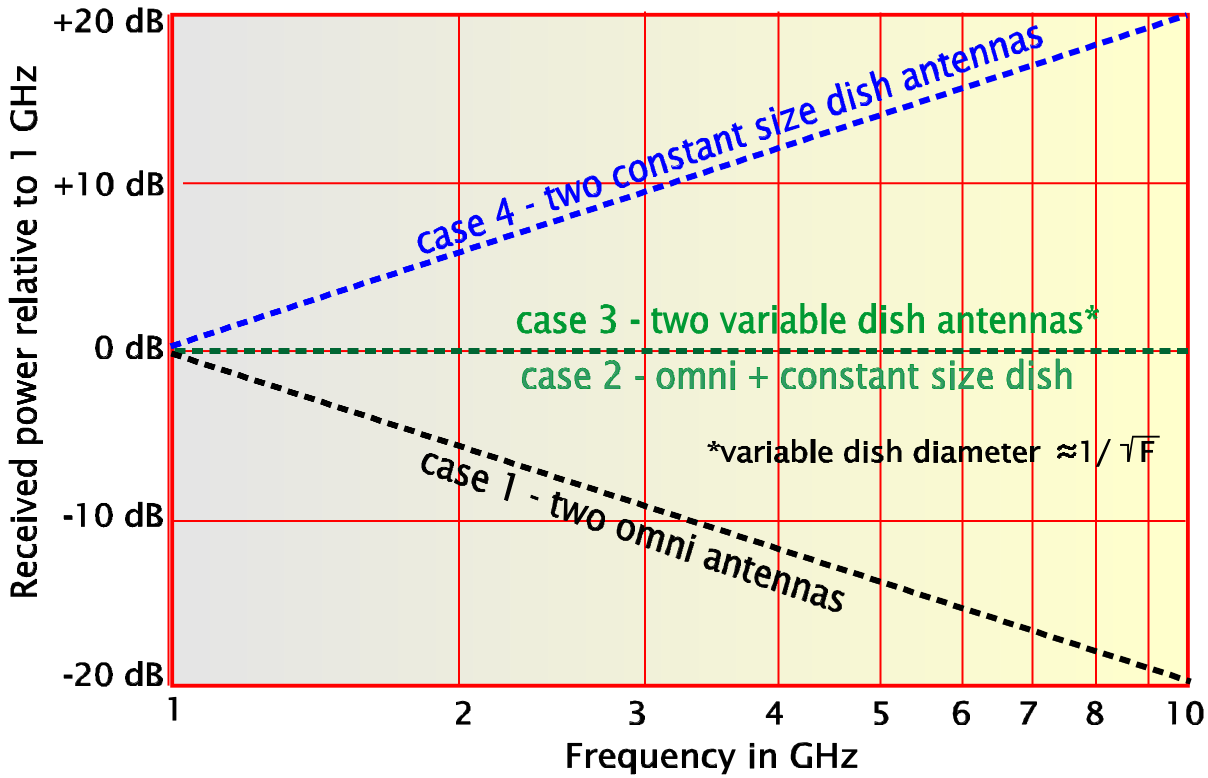
Higher path loss has been cited as a reason that higher frequencies are unsuitable for wireless ap-plications.

1. Use shorter paths and get higher frequency re-use.

2. Take advantage of higher antenna gain and get greater directional re-use.

3. Or, whatever.

4. Denser infrastructure.



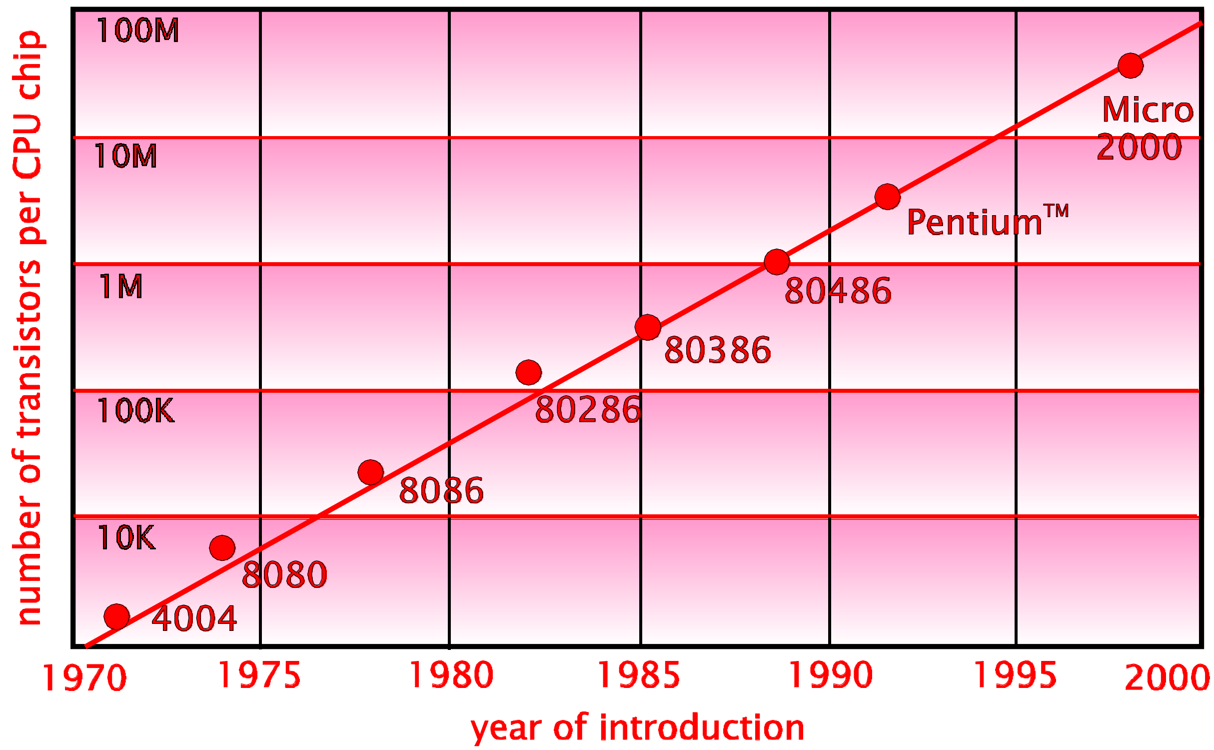
Smart Systems

Moore's Law of CPU complexity

New systems depend heavily on intelligence to keep track of mobile users, ensure privacy and proper billing, route data to proper site, share system resources, compress data, correct errors, present data, etc.

1. Systems will continue to get more complex.

2. Decreasing cost of computation will shift additional functions from hardware to software.



Digital Convergence

"A one is a one is a one." – apologies to Gertrude Stein

- ✰ Conversion to digital allows every type of message to be carried.
- ✰ Each system can do everything – voice, video, paging, Internet
- ✰ Different services morphing into each other.
  - Cable TV   TV + telephone + Internet + videophone
  - LMDS TV   TV + telephone + Internet + videophone
  - Telephone   TV + telephone + Internet + videophone
  - Etc. for MMDS, 24 GHz WLL, 38 GHz "wireless fiber"
- ✰ Differences: mobility, antennas, coverage, bandwidth, latency, cost
- ✰ Which frequency, architecture, pricing, packaging, etc. is best?

Adaptive Antennas

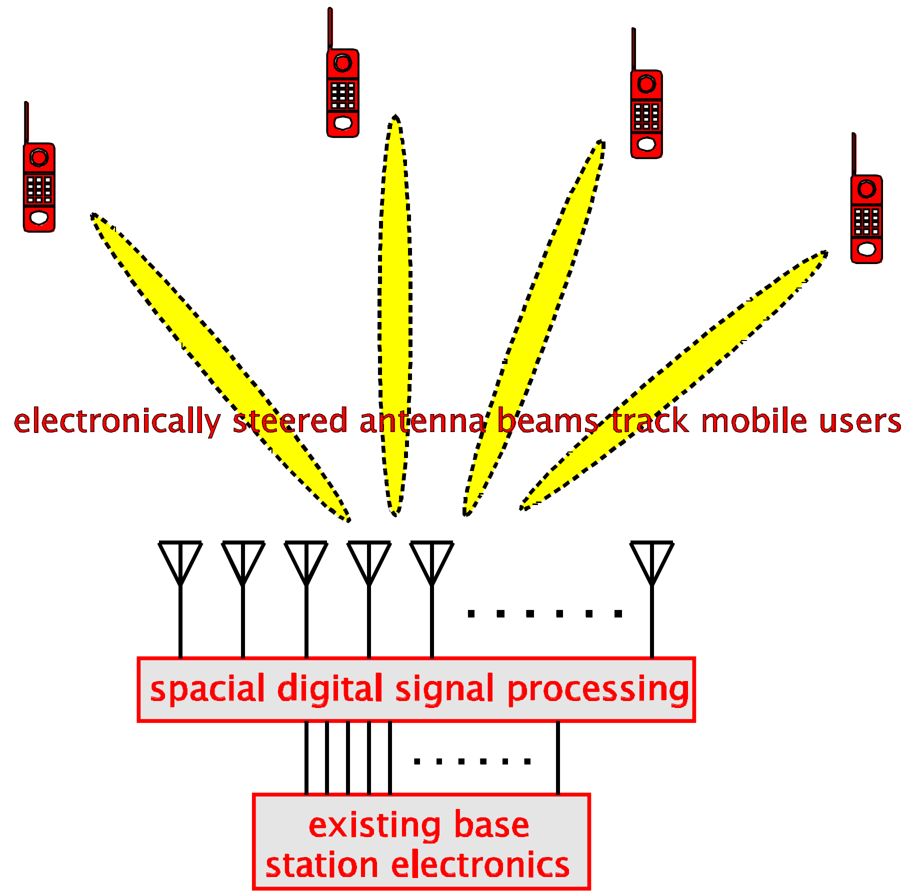
Adaptive antennas move closer to the ideal of establishing a narrow-beam one-to-one path between a base station and each mobile unit.

✰ Increased base-station capacity and frequency reuse.

✰ Improved diversity, range, and multipath distortion factors.

✰ Substantial increase in system complexity and digital processing demands.

✰ Complex antenna arrays are smaller and cheaper in the higher frequency bands.



Non-technical Issues

Some new non-technical issues that will affect wireless systems

- ✰ A variety of operating rules (spectrum property rights?)
- ✰ Intense and genuine competition. Who will succeed?
- ✰ Globalization
- ✰ Standardization

Spectrum property rights

Wide variety of property rights in various bands. Which is best for what?

- Flexible property rights vs. specific service rules.
- Auctioned. Limits on power outside geographical area. Owned? Complete flexibility in use, but large up-front payment.
- Traditional license. Cheap. Often shared. Very specific uses.
- ISM/Part 15.   Non-licensed. No protection from interference. Spread spectrum, WLANs, cordless phones. Cheap.
- Unlicensed PCS - Spectrum protocol to avoid interference

Competition

Intense competition, with many systems providing the same services.

- ✰ Digital convergence. Many technologies, all providing same set of services (very valuable services, to be sure).
- ✰ How many will succeed? How many will fail?
- ✰ How many competitors are desirable? Reverse economies-of-scale. Telco vs. cable vs. MMDS vs. LMDS vs WLAN vs ...
- ✰ With cross-service competition, is in-service competition needed?

Large-scale systems?

Many forces driving entrepreneurs to consider only large-scale systems.

- Global systems and markets- e.g., LEO satellites must be global
- Systems are very complex – How many engineers does it take... ?
- Standardization
  - Interoperability
  - Economies of scale – IP is larger; manufacturing is smaller
  - Develop and access Global markets

  - Externalizes part of complexity and development cost
  - Defines interfaces – entrepreneurs focus on part of the problem.
  - Minimizes consumer learning demands - rapid acceptance of new

Heresies?

Sometimes you need to ask, even when you don't want the answer.

- ☆ Has the availability of too much spectrum, encouraged us to build too many competing systems?
- ☆ How soon can we absorb the capacity of LMDS, digital cable, MMDS, mobile satellites, wideband satellites, ATV, PCS, 3G, WLANs, wireless data, Will the markets be there when the systems are?
- ☆ Why are there "build-out" requirements on auctioned spectrum?
- ☆ Will building many systems with Tomorrow's Technology hurt us on the Day-after-Tomorrow?

Conclusions

- ✰ The development of future wireless systems will be exciting, very competitive, very demanding technically and creatively.
- ✰ Spectrum availability will probably not be a major problem. Higher frequencies (where the bandwidth is) present an intriguing set of advantages and disadvantages.
- ✰ New systems will be very different from traditional systems. They will be very smart, very complex, digital, multi-purpose, and indispensable for modern life.
- ✰ I can hardly wait to see what you come up with!