How Spectrum Policy Enables Wireless Innovation: Wi-Fi and Bluetooth Origins

Michael J. Marcus, Sc.D., F-IEEE

Federal Communications Commission (Retired)
Director, Marcus Spectrum Solutions LLC
Adjunct Professor, VT ECE

mjmarcus@alum.mit.edu
www.marcus-spectrum.com

Why is this important, I just do wireless R&D?

- Regulation of wireless technology is a fact of life worldwide
  - Greater role than in most other electrotechnologies
- While general trend is towards deregulation, significant regulatory issues for new technologies will persist for the foreseeable future
- Knowledge of this issue will help you in getting innovative technology into practical use

Wireless is Different!

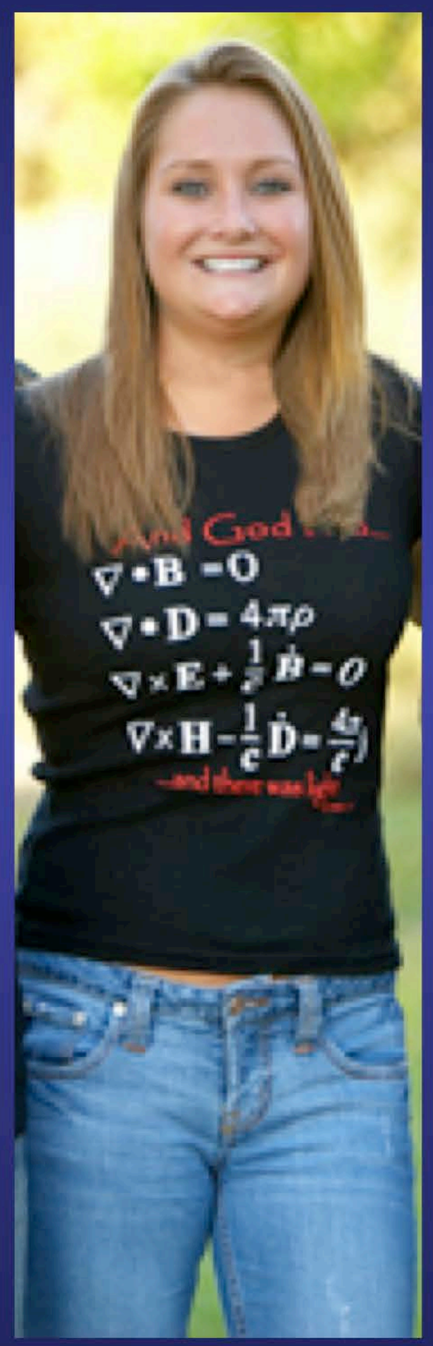
Both regulations and standards play a large role in wireless

Federal Communications Commission

American National Standards Institute

Wireless is Different!

For the designer of equipment for civil markets, regulations and standards issues are just as <u>real</u> as Maxwell's equations



Spectrum Regulations vs. Maxwell's Equations

- Both are *real*
- Maxwell's Equations are not going to change
- Spectrum Regulations do change and can be "pushed" for change
  - But change is neither instant nor 100% certain
  - Knowledge of "time constants", sources of help, and realistic risks are essential for good business planning

Wireless is Different!

- Why?
  - Spectrum is a shared resource
  - In early days of radio “free for all” lead to reported chaos
  - 1920s anticompetitive behavior of Marconi Corp., AT&T, and RCA raised concerns about fair competition

Changes

- Basic framework of radio regulation set up in aftermath of the *Titanic* disaster

Assumptions:

THEN

- Safety services will be a very large user
- Long distance is major need for radio
- Poorly understood propagation with ionosphere playing big role
- "High frequency" (3-30 MHz) was thought to be really "high"
  - Bandwidth limited
- Throughput/MHz fixed

NOW

- Many nonsafety services serving all aspects of economy
- Major demands for short radio links
- Propagation much better understood
  - Terrain shielding and low atmosphere weather have large impact
- Highest frequency in commercial use now 77 GHz
- Throughput/MHz usually related to fixed costs

Changes

THEN

- Technology moving slowly, few technical choices
- Big government a good idea, little trust in marketplace forces
- Nationalization and detailed regulation of private entities desirable
- Government use of spectrum regulated differently

NOW

- Technology moving at “internet speed”, much faster than government policymaking
- More faith in marketplace choices
- Denationalization and regulation focused mainly on externalities
- Maybe not …

Origins of Wi-Fi/Bluetooth

- Roots are twofold:
  - Technological
  - Spectrum Policy
- Convergence of the two at FCC in the 1980s enabled a unique blossoming of technologies in a field normally subject to "command and control" policies

Origins of Wi-Fi/Bluetooth

- FCC action was a self initiative
- Was not focused on either external petitions or WLANs
  - Subsequent more focused proceedings (U-PCS and U-NII [and HIPERLAN in Europe]) were less successful

Traditional FCC Spectrum Policy

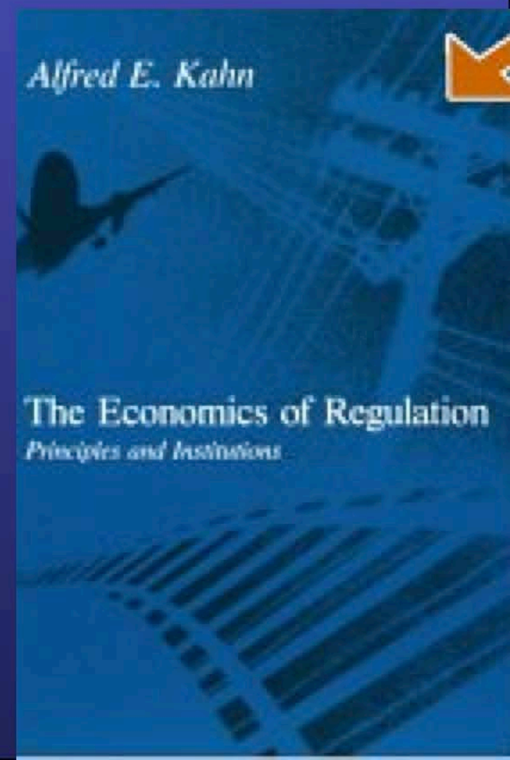
- Has its roots in the 1930s
  - When frequencies were limited
  - Technological options few
  - Faith in government high
  - Rules could be easily changed
- But these all changed with
  - Post-WWII technological explosion
  - 1946 Administrative Procedures Act
- Just as new technology became available, regulations slowed down!

Traditional FCC Spectrum Policy

- FCC (and other spectrum regulators) traditionally depended on petitioners spelling out “requirements” and then specifying band and technology to meet such “requirements”
- Hard to impossible to keep up with technological change and needs of a changing society and economy

Deregulation Comes to FCC
(and Stays)

- Carter Administration brought a focus on deregulation as a means to stimulate economic growth
- CAB Chairman Alfred Kahn was a leader within administration on the effectiveness of deregulation
- FCC Chairman Ferris embraces concepts
  - For Both Titles II and III



Chmn. Ferris & Spectrum

- Chmn. Ferris challenges his spectrum team to identify promising technologies that are blocked by anachronistic regulations
  - Recognizes the delay and transactions costs associated with waiting for petitions in all cases
  - Goal was not to force new technology but get out of its way

Searching for Candidate Technologies

- Ferris recruits former ARPA chief Steve Lukasik to head Office of Science & Technology starting in Summer of 1979
  - Challenges him to identify candidate technologies to remove barriers from
  - New emphasis on market forces not "command & control"

Serendipity in Action

- I encounter Lukasik in May 1979 at a classified Army Science Board electronics warfare panel meeting in Chicago
  - Had previously met while I administered ARPA R&D projects in nuclear test detection during military service
  - Due to Army efficiency, “MA” certain to sit next to “LU”!!
  - Electronic warfare similar to spectrum management except for intent

Serendipity in Action

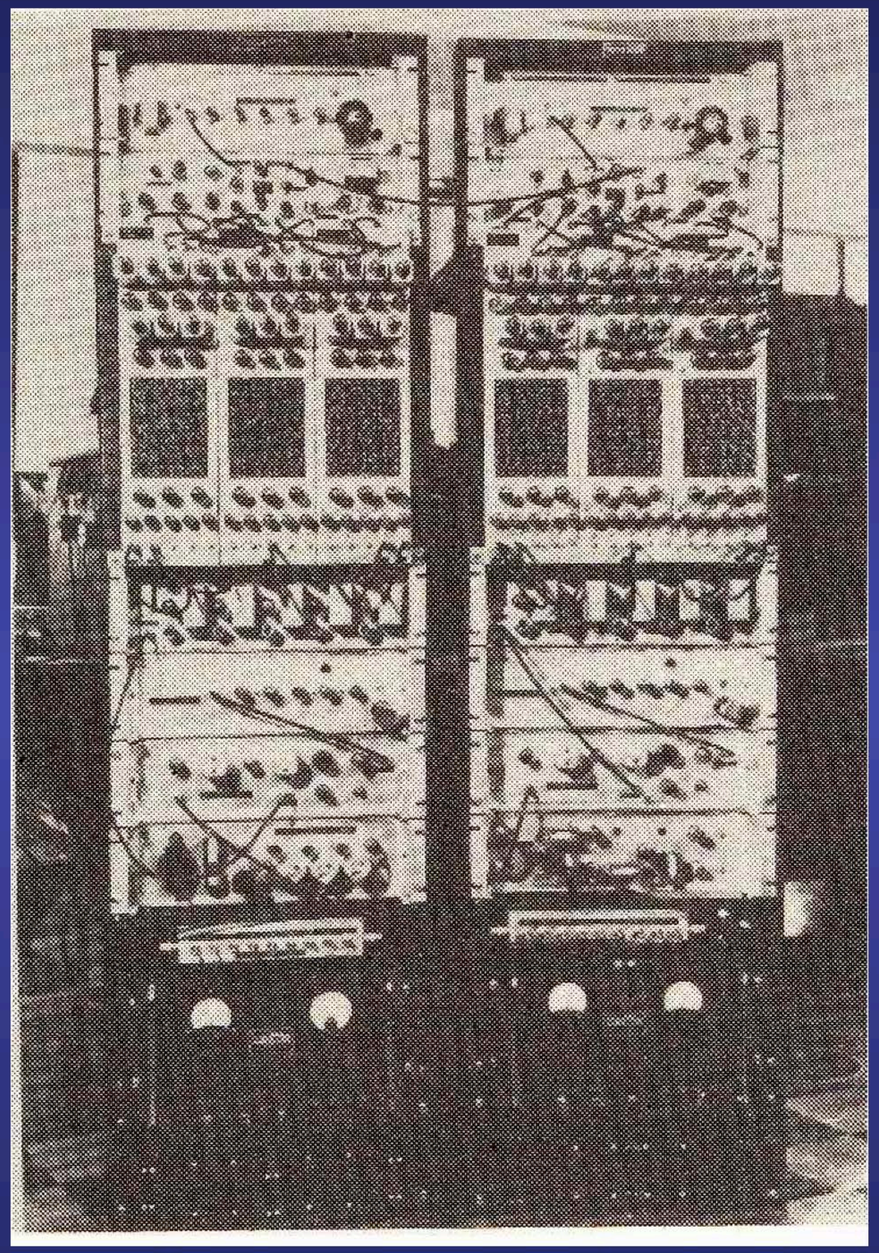
- Chicago encounter leads to question:
  - What radio technologies might bloom if dated regulations were removed?
- Within a few days reply with list:
  - Spread spectrum
  - Adaptive antennas
  - Millimeter wave bands (>30 GHz)
- Lukasik replies with job offer at FCC
  - My ticket out of military-industrial complex

Spread Spectrum Background

- Like the computer, the basic technology, spread spectrum, has no single specific inventor
- As is often reported in popular press, Hedy Lamarr was awarded an early frequency hopping spread spectrum patent during WWII

  - But invention was not reduced to practice

1953 MIT Lincoln Lab System



- Developed by Paul Green as a thesis project
- One of earliest PN systems
- Technology of the day limited size

Dixon's Book 1975

- First comprehensive, though mathematically inelegant, treatment of spread spectrum
- Introduced a generation of designers to the technology

Early FCC Action - Phase I

- FCC had encountered MITRE Corp. in connection with deliberations of JTIDS use of L band
- First FCC step in 12/79 was commission MITRE for a report on options for civil use of spread spectrum
  - Since then FCC has <u>never</u> commissioned such a report unless ordered by Congress


Potential Use of Spread Spectrum Techniques
in Non-Government Applications

Walter C. Scales

Available from NTIS as PB81-165284

MITRE Report

6.3 Potential Applications

Although it is obviously not possible to predict specific applications that the FCC will be asked to license, it may be useful to identify the potential applications that have been proposed to date. Of these, potential land mobile applications using fast frequency hopping have dominated in the area subject to FCC licensing. Although a significant amount of analysis has been performed in this case, little or no experimental activity is evident, and implementations in the near-term seem unlikely, except possibly on an experimental basis. The prospects for the realization of such systems is weakened by their potentially high cost, although future technological breakthroughs could negate this factor.

←Not very useful in hindsight

Frequencies allocated for Industrial, Scientific, and Medical (ISM) purposes provide for the unlicensed operation of devices which use radio waves for the purposes other than communication. Such devices include, for example, medical diathermy equipment, industrial heating equipment, and microwave ovens. Because of the inherent interference resistance of spread spectrum receivers, it is logical to examine the possibility of operating spread spectrum systems in these bands.

←Very useful and significant

6/30/81 - The Regulatory Struggle Begins

- 2 initiatives begun:
  - Chmn. Fowler supports action
  - Docket 81-413 – General use
    - Docket 81-414 – Amateur radio use
- No specific proposals
  - “designed to serve two purposes. We hope to gather information to: 1) assist us in identifying specific radio services presently authorized by the Commission, as well as ideas for new services, where the authorization of wideband modulation techniques would serve the public interest; and 2) identify the technical parameters which characterize a wideband emission, including procedures used to measure these parameters, and identify technical standards necessary to insure operation on a minimum interference basis.”
- Do not mention unlicensed or RLANs but does mention ISM bands

Response to NPRM

- “Of the parties submitting comments that opposed the proposed authorization of spread spectrum systems, RCA was the only one that supported its position with analysis. RCA's analysis dealt with possible interference to FM and television broadcasting from spread spectrum systems operating in the broadcast bands.”
- NIMBY and fear of overlays is major concern
- 2 IEEE groups file supportive comments
- Chairman Fowler supportive of deregulatory concepts

Before the
Federal Communications Commission FCC 85-245
Washington, D. C. 20554 35747

In the Matter of)
)
)
Authorization of spread spectrum and other) GEN DOCKET NO. 81-413
wideband emissions not presently provided)
for in the FCC Rules and Regulations.)

FIRST REPORT AND ORDER

Adopted: May 9, 1985 Released: May 24, 1985

By the Commission:

INTRODUCTION AND SUMMARY

1. Spread spectrum modulation is a wideband modulation which was originally developed for military applications but which has several interesting civil applications 1/. This technology has been implicitly forbidden by the FCC rules with a few limited exceptions. On June 30, 1981, the Commission adopted a Notice of Inquiry ("Inquiry") 2/ in this proceeding seeking comments on a rule structure that would permit civil use of this technology 3/.

1/ The spreading or dilution of the energy in spread spectrum systems over a wide bandwidth results in several possible advantages: short range overlays on other emissions, resistance to interference from other emissions, and low detectability. While it is not anticipated that spread spectrum will replace other types of modulations in general, the unique characteristics of spread spectrum offer important options for the communications system designer.

2/ 87 FCC 2d 876

3/ A companion Notice of Proposed Rulemaking was adopted in Docket 81-414 proposing use of spread spectrum in the Amateur Radio Service and has been implemented, in part, in a Report and Order we are adopting today.

1985

- May 9, 1985 FCC adopts spread spectrum rules in ISM bands
- Same basic rules until 2002
  - 1 W limit
  - PN or FH
  - Almost any application
- QUALCOMM incorporated July 1985

7/87 *IEEE Communications Magazine* Article

The rule change which is most relevant to the radio LAN application is contained in Section 15.126 of the FCC Rules [11]. This allows unlicensed transmitters of an approved design to transmit up to 1 w of spread spectrum emissions in any of the following bands: 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz. The minimum spreading permitted is specified in the rules for both direct sequence and frequency hopping systems. These systems can be used for any application such as radio LAN's and cordless microphones but are secondary (must not cause interference to other users and can not complain about interference received) to other uses of these frequencies such as microwave ovens in the case of the 2400 MHz segment, radar systems, and amateur radio in the case of the 900 MHz segment.

While no one has marketed a system under the provision of these rules to date, it appears feasible to design a radio LAN with these provisions with a range of 100–200 m. Amateur radio use of the 900 MHz band is rare at present and in any case will usually be limited to residential areas. Although industrial radio frequency heating equipment is permitted in all three bands, such

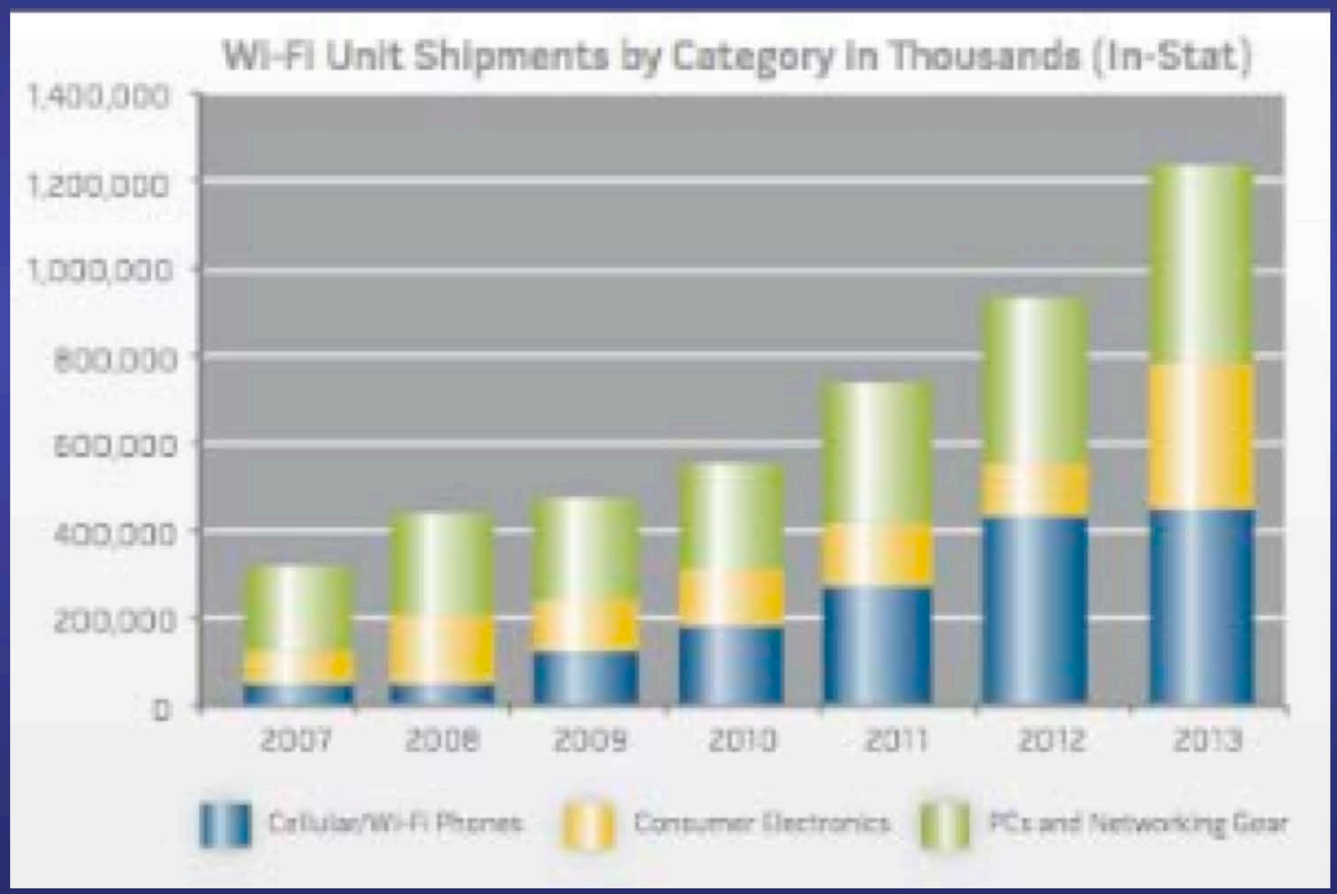
- Gave a paper on new rules at GLOBECOM '85
  - FCC management tried to prevent such discussion
- 7/87 update of paper raised possibility of RLANS in ISM bands

“First Light”

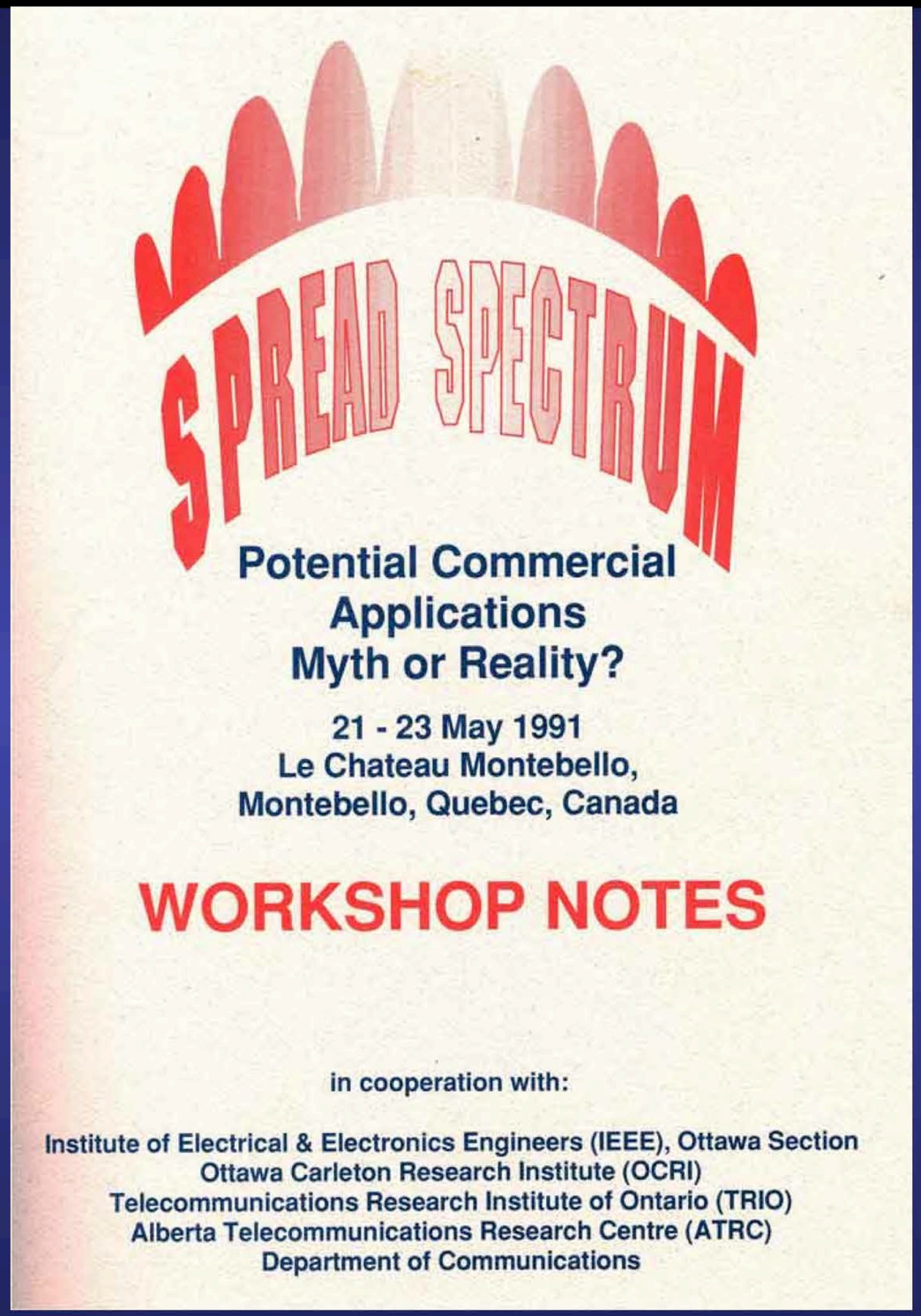
- In 1988 the first real commercial spread spectrum product appeared – an RLAN

Equipment Trends

- After slow start, equipment authorizations has had exponential growth



1991



- "Myth or Reality"
- Many key players went to Quebec woods to discuss the future of spread spectrum

Lessons Learned

- Since technology moves faster than regulations, there are often anachronistic regulations that block new technologies
- Transactions costs of changing regulations decreases interests in technologies adversely affected
- Removing barriers to new technology while maintaining a level playing field can stimulate innovation

ECE 5984

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Unleashing Unlicensed

How Wi-Fi Got Its Regulatory Groove

April 4, 2008: An IEP Conference at GMU

Thanks for Listening

Questions?

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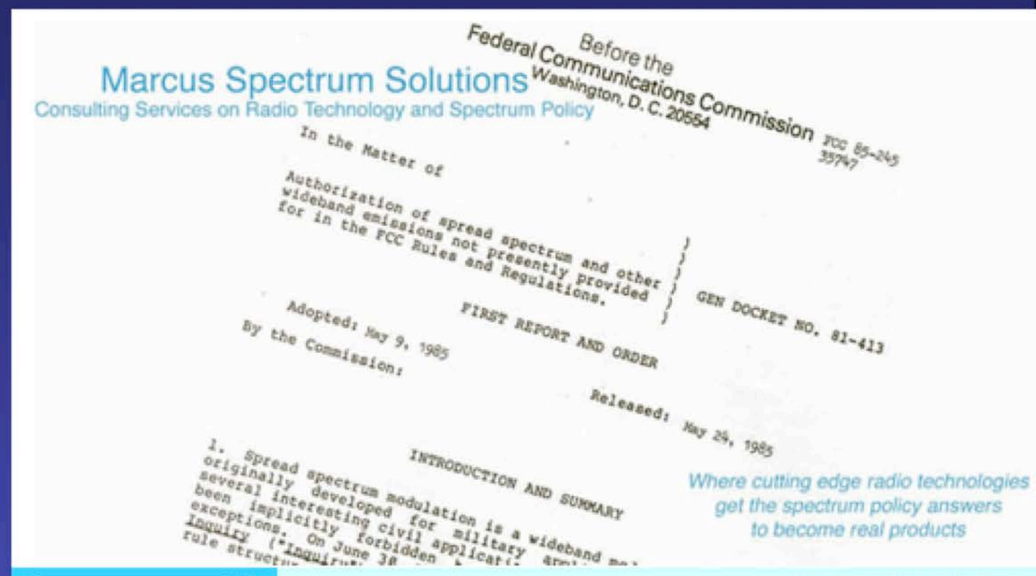
More info on website


Marcus Spectrum Solutions
Consulting Services on Radio Technology and Spectrum Policy

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FCC 85-245
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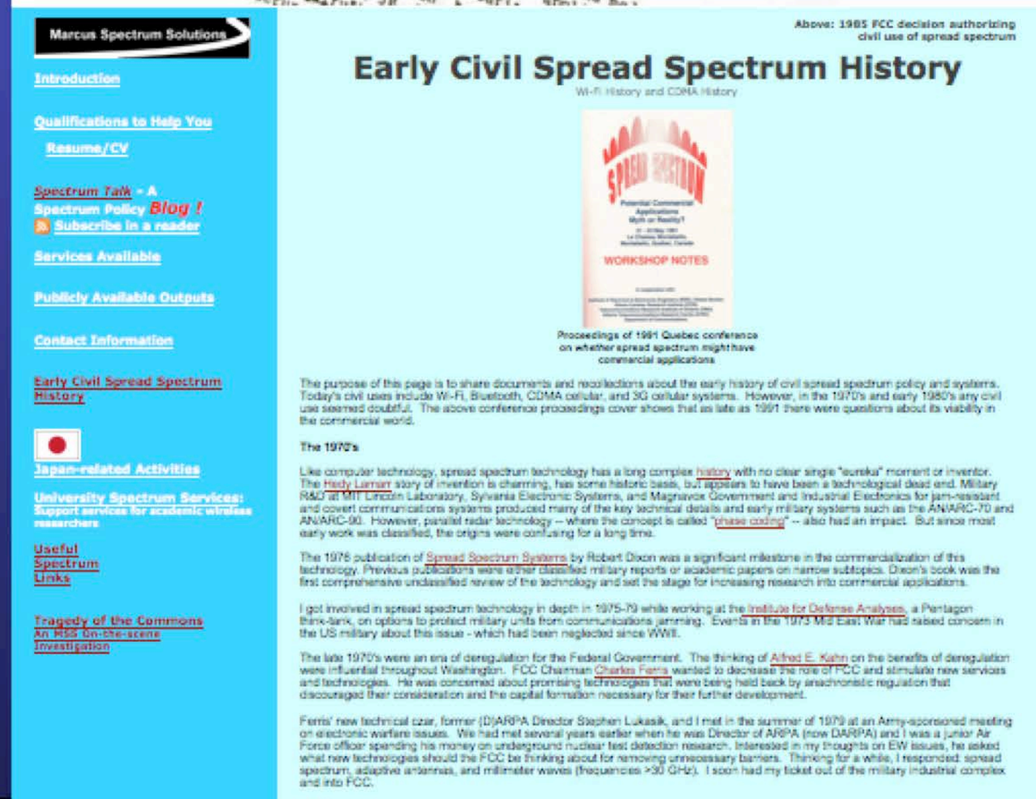
Where cutting edge radio technologies get the spectrum policy answers to become real products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Introduction

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Early Civil Spread Spectrum History

Japan-related Activities

University Spectrum Services: Support services for academic wireless researchers

Useful Spectrum Links

Tragedy of the Commons An MSS on-the-scene Investigation

Above: 1985 FCC decision authorizing civil use of spread spectrum

Early Civil Spread Spectrum History

Wi-Fi History and CDMA History

Proceedings of 1991 Quebec conference on whether spread spectrum might have commercial applications

The purpose of this page is to share documents and recollections about the early history of civil spread spectrum policy and systems. Today's civil uses include Wi-Fi, Bluetooth, CDMA cellular, and 3G cellular systems. However, in the 1970's and early 1980's any civil use seemed doubtful. The above conference proceedings cover shows that as late as 1991 there were questions about its viability in the commercial world.

The 1970's

Like computer technology, spread spectrum technology has a long complex history with no clear single "eureka" moment or inventor. The Hedy Lamarr story of invention is charming, has some historic basis, but appears to have been a technological dead end. Military R&D at MIT Lincoln Laboratory, Sylvania Electronic Systems, and Magnavox Government and Industrial Electronics for jam-resistant and covert communications systems produced many of the key technical details and early military systems such as the AN/ARC-70 and AN/ARC-90. However, parallel radar technology -- where the concept is called "phase coding" -- also had an impact. But since most early work was classified, the origins were confusing for a long time.

The 1978 publication of Spread Spectrum Systems by Robert Dixon was a significant milestone in the commercialization of this technology. Previous publications were either classified military reports or academic papers on narrow subtopics. Dixon's book was the first comprehensive unclassified review of the technology and set the stage for increasing research into commercial applications.

I got involved in spread spectrum technology in depth in 1975-79 while working at the Institute for Defense Analyses, a Pentagon think-tank, on options to protect military units from communications jamming. Events in the 1973 Mid East War had raised concern in the US military about this issue - which had been neglected since WWII.

The late 1970's were an era of deregulation for the Federal Government. The thinking of Alfred E. Kahn on the benefits of deregulation were influential throughout Washington. FCC Chairman Charles Ferris wanted to decrease the role of FCC and stimulate new services and technologies. He was concerned about promising technologies that were being held back by anachronistic regulation that discouraged their consideration and the capital formation necessary for their further development.

Ferris' new technical czar, former (D)ARPA Director Stephen Lukasik, and I met in the summer of 1979 at an Army-sponsored meeting on electronic warfare issues. We had met several years earlier when he was Director of ARPA (now DARPA) and I was a junior Air Force officer spending his money on underground nuclear test detection research. Interested in my thoughts on EW issues, he asked what new technologies should the FCC be thinking about for removing unnecessary barriers. Thinking for a while, I responded: spread spectrum, adaptive antennas, and millimeter waves (frequencies >30 GHz). I soon had my ticket out of the military industrial complex and into FCC.