Wi-Fi and Bluetooth - The Path from Carter and Reagan-era Faith in Deregulation to Widespread Products Impacting Our World

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Introduction

On May 9, 1985 the Federal Communications Commission (FCC), in a meeting that attracted little attention outside the few companies that lobby the agency, adopted a set of rules dealing with the esoteric topic of spread spectrum modulation. But like a seed planted in the ground, these rules resulted in the germination of new classes of products that ultimately had both significant economic impact as well as impact on the daily lives of many people. This decision did not start as an attempt to bring specific products to market, but as part of a program to remove anachronistic technical regulations and allow a free market in innovative technology, subject only to responsible interference limits.

Historically, most spectrum policy decisions at FCC have originated in petitions filed by large corporations, or at least corporations with powerful legal representation. The usual way to resolve spectrum policy controversies at FCC has been to either encourage the parties involved to reach a compromise consensus or to make a Solomonic decision splitting the differences between the parties. (Since the FCC views itself as the "expert agency" in spectrum management, this reticence to make independent decisions seems a little odd.)

The May 1985 spread spectrum decision was unusual in that it came from a bold policy initiative, started under one chairman and finished under his successor (from a different party), that was strongly opposed by almost all the vested corporate interests that dealt with FCC. The success of this 1985 decision may show that consensus-based decision-making, although appropriate for many or even most issues, should not be the sole policy tool for future FCC decisions. It also shows that planning for the future can give long-term benefits beyond the term of one chairman.

The regulatory decisions involved were not the classic "command and control" approach that predicted demand or "requirements" for new services and then selected spectrum and

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technology to meet the anticipated demand (that might actually come or not). Rather they were decisions based on removing anachronistic barriers to technology and having faith in marketplace forces to use the newly available technology for its highest and best use. They were also "fail/safe" decisions that obligated no one to use a specific technology and displaced no existing users. If removing the barriers to spread spectrum had resulted in no new equipment or services, the only cost to society would have been the cost of the rulemaking and the paper consumed by the one page of rules in the annual *Code of Federal Regulations*. This was in keeping with the general deregulatory approaches of both the Carter and Reagan Administrations.

Personal Pre-FCC Involvement with Spread Spectrum

I finished a doctorate in electrical engineering in the Fall of 1971 and headed off for a long tour of Europe while I waited for the Air Force to call me to active duty in this waning time of the Vietnam War. I had been in ROTC at MIT and the Air Force had paid most of my undergraduate tuition in exchange for a 4-year commitment and a draft deferment during my undergraduate and graduate education. In January 1972 I was ordered to the Washington DC area and given an assignment dealing with underground nuclear test detection research – basically transporting and processing signals at frequencies of less than 1 Hz. It was an odd beginning of a career that would focus on radio and span the microwave bands!

The first month I was on the job, office colleagues suggested that I take advantage of my new security clearance and get out of the office for 2 days to attend the classified portion of the annual IEEE EASCON conference in the Washington area. It was at this meeting that I first heard of the concept of spread spectrum during a classified session on military jam resistant communications. I was both puzzled by the technical details and by the fact that I had never encountered even a hint of this technology in my MIT studies. Fortunately an office colleague, Capt. John Woods, explained the basic details of the technology. Later I found out that the basic facts of the technology were in the open literature, but were scattered in many isolated articles on different technical issues. There was no concise overview that was generally available.

The details of this were then filed away for the rest of my Air Force service, which focused on seismic issues far away in frequency from the spread spectrum radio systems. It turned out that our office was mainly funded by the Pentagon's Advance Research Projects Agency (ARPA, now the Defense Advanced Research Projects Agency – DARPA). The ARPA director, Dr. Stephen Lukasik, took a strong interest in our program, both because of its political significance at the time and because of the fact that he had earlier worked in related areas. Thus I managed to meet him several times during my period in the office.

With the winding down of the Vietnam War, I was released from the Air Force in May 1975 and started looking for other employment. The Institute for Defense Analyses (IDA), a Pentagon think tank then located within walking distance of the Pentagon, was interested in both my technical background and security clearances for what turned out to be a study of the electronic warfare lessons of the 1973 Yom Kippur War and how they might be applied to the newly recognized threat of Soviet communications jamming in the event of a Warsaw Pact invasion of W. Germany that was the focus of Cold War planning.

The obvious technical solutions to this threat were spread spectrum modulation, because of its resistance to undesired signals, and adaptive antenna systems, because of their ability to reject signals based on their nature and azimuth. The main focus of my time at IDA was thus studying the application of these concepts to military systems as well as other defensive measures that might be of value.

In May 1979, serendipity played a key role in my future and the future of civil spread spectrum technology. Based on my work on communications jamming issues, I was invited to a two-day classified Army Science Board meeting in Chicago on the topic. Also at the meeting was Dr. Lukasik, the former ARPA director. Now the Army is very organized and had assigned seats in alphabetical, order so it was inevitable that no one would be between "LU" and "MA," and Dr. Lukasik and I sat together for the whole meeting. He remembered me from Air Forces days and was impressed with my discussion of jamming issues – which are mathematically the same as unintentional radio interference issues. He mentioned that he had accepted a job at FCC as Chief Scientist and would shortly start there. He then mentioned a challenge he had received from FCC Chairman Charles Ferris to identify new technologies that were being blocked by anachronistic regulations and to find ways to level the playing field for them. He then asked me to think about what technologies I was familiar with that might have such characteristics.

Calling him back a few days later, I proposed three possible technologies: spread spectrum, adaptive/smart antennas, and millimeter waves (frequencies greater than 30 GHz). In a few days I had an informal job offer from FCC and was on my way out of the military industrial complex into the civil technology world. By mid-September, I was on the FCC payroll as Special Assistant for Technology Planning to the FCC's new Chief Scientist, Dr. Lukasik.

Arrival at FCC and Phase I

Arriving at FCC on a Thursday, I worked 2 days and then went on a weekend retreat near Harper's Ferry, WV, with Chairman Ferris and most of the FCC's top managers, on the subject of spectrum policy and what initiatives might be taken. (My wife observed that in this first week on the job I got paid for 2 days and worked four days.)

From the retreat discussions and later ones, it became clear that spectrum regulations are generally written to reflect the technologies available at the time and reasonably anticipated in the future. So it is inevitable that the underlying assumptions of spectrum regulations will become dated as new technology is introduced and new services become of interest. As these regulations become dated they unintentionally discourage investment in alternative technologies that are explicitly or implicitly prohibited or put at a disadvantage in the applicable regulations.

Other technical areas without prescriptive regulations, *e.g.* semiconductors and computer technology, then become more attractive for investment and R&D. New products in such areas can reach markets quickly, without timely regulatory battles that give competitors time to delay or prevent market access of the new technology and/or to take advantage of information filed in regulatory proceedings to copy the innovation to minimize the innovator's technology lead. Transaction costs, such as legal fees and overhead while waiting regulatory approval, faced by the innovator in clearing regulatory barriers result in sunk cost expenditures that disadvantage the innovator relative to later entrants. So basically, innovative radio technology faced high entry barriers that discouraged new entrants and the investors they needed.

In the 1970s the spectrum technology area was highly concentrated, with only a few major manufacturers: Western Electric was the near exclusive supplier of the local and long distance telecommunications industry, cellular was in its experimental stage, and the regulatory *status quo* was rather acceptable to the small "club" of major manufacturers serving the US market, all of whom were domestic companies. While regulations prevented rapid innovation, it also generally prevented both new entrants and technological surprise from the few competitors. Products could be planned and introduced with assurances that the R&D costs could be amortized over a long sales period. It was a cozy oligarchy for the major manufacturers, but it denied the public the benefits of rapid introduction of new technologies and services just as in the parallel Bell System telecommunications monopoly.

In its early approach to spectrum regulation in the 1930s, FCC had taken the approach of specifically enumerating allowed uses of spectrum and allowed technologies. At that time, usable spectrum was scarce, both due to the inefficiencies of available radio technology (e.g. mobile radio had 100 kHz channels whereas now the equivalent of 7.5 kHz is standard) and to the fact that the maximum usable frequency with affordable technology was a few hundred MHz. Also at that time FCC had a pretty casual approach to deliberating on and adopting new rules, as today's Administrative Procedures Act (APA)[1] did not yet exist. Thus FCC could adopt rather detailed regulations and quasi-regulatory standards and change them rather easily as the need arose -- which was not very often since radio technology was moving slowly at the time.

However, with World War II there were major changes. Radio technology, like many other technologies, benefited greatly from wartime R&D and when the war was over, the upper usable frequency had moved into the few GHz range and many new applications and new technologies were available. But at the same time, a delayed reaction to the great expansion of federal regulation during the New Deal resulted in the formal procedures of what we know as rulemaking today with the passage of the APA in 1946. Subsequent court cases that helped define what "notice and comment" rulemakings really

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[1] 5 USC §553

were and what was "arbitrary and capricious" agency action.[2] Thus at the very time when there was an increased need to change prescriptive spectrum regulations to keep up with rapidly changing technology, the APA effectively grandfathered in existing regulations and made updating them more difficult and time consuming. The decision a decade or so earlier to adopted generally prescriptive rules was now becoming a major burden and hindrance to technological innovation.

Civil Aeronautics Board Chairman Alfred Kahn had been very influential in the Carter Administration in establishing deregulation as a method to improve the efficiency of industries and to speed economic growth. FCC Chairman Ferris saw this as a goal for FCC and established a broad deregulatory agenda, in many cases building on previous FCC actions. It was this background that had made Ferris and Lukasik interested in technologies that could be allowed to "seek their own level" through technical regulation that created a "level playing field" for all technologies, subject to reasonable regulations to prevent interference.

So with this background we started our spread spectrum deregulation project shortly after my arrival at FCC in September 1979. My two other original deregulatory ideas, adaptive antennas and millimeterwave, were considered as possibilities but given lower priority since they were less mature technologically at the time. The spread spectrum goal at the time was not to introduce a specific class of products, such as wireless local area nets, or even a specific band, but rather to create relatively clear opportunities for this technology to reach market in order to encourage investment in R&D.

Some academic R&D was going on at the time in the area of what would now be called code division multiple access (CDMA) for land mobile systems.[3] But the main impact of this R&D was to arouse the opposition of a major mobile equipment manufacturer that saw such a major technological change as a threat to its market hegemony. At the time, the essential role of strict automatic transmitter power control (ATPC), later pioneered by Qualcomm and a key part of today's CDMA, was not well understood. FCC staff did not anticipate at the time that spread spectrum would be a possible technology for general land mobile applications, *e.g.* CDMA cellular, but rather that it could be valuable in at least niche applications. In what presaged the deliberations and controversy at FCC on ultrawideband (UWB) two decades later, FCC staff also thought that spread spectrum

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[2] Readers from civil law countries should recognize that the true meaning of the APA in the US common law system is not the short text of the law but rather the numerous court decisions over the years interpreting it.

[3] Cooper, G.R. and Nettleton, R.W., "A spread-spectrum technique for high-capacity mobile communications", *IEEE Transactions on Vehicular Technology*, Volume *VT-27*, No. 4, P. 264 - 275 (Nov 1978)

overlays[4] could be used to extract extra capacity from existing bands for short distance communications.

Prior to my arrival at FCC, FCC personnel had arranged for a special short course on spread spectrum technology at George Washington University to acquaint the staff with this new technology. FCC deliberations had previously touched on this technology when the Defense Department proposed use of the Joint Tactical Information Distribution System[5] (JTIDS) in the 969 MHz to 1.206 GHz band. This band overlapped civil use by Air Traffic Control Radar Beacon Systems and Distance Measuring Equipment,[6] and the proposed overlapping military use raised novel technical issues at the time and was quite controversial. At the short course, FCC staff encountered a MITRE Corporation staffer, Dr. Feisal Keblawi, and began a dialogue on long-term implications of this technology for civil spectrum management at FCC.[7] Based on these initial discussions, in December, FCC gave a contract for $55,652 to MITRE Corporation to explore potential civil uses of spread spectrum and the spectrum policy implications of such use.

It is interesting to note that since then FCC has *never* contracted for any analogous study of technical policies issue, except in isolated cases where the agency received specific Congressional direction for outside studies. However, such studies are common at other regulatory agencies that deal with technical issues, and I believe the lack of such studies is a continuing problem at FCC.[8] In terms of long-term benefit to the US economy, the cost of this contract was probably the best investment FCC ever made!

The MITRE report, authored by Walter Scales, was released in December 1980. It is a good snapshot of what was known at the time about civil applications of spread spectrum

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[4] Since this time spectrum jargon has changed somewhat. At the time "overlays" meant low power spectrum density applications existing overlapping narrowband users. Now this is often called "underlays" and the term "overlays" is often used for cognitive radio-based systems that insert narrowband signals in temporarily vacant holes between other narrow band signals.

[5] https://wrc.navair-rdte.navy.mil/warfighter_enc/weapons/SensElec/Sensors/link16.htm

[6] B. Kobb, *Wireless Spectrum Finder*, McGraw-Hill, 2001, p. 170-171.

[7] W. Scales, "Potential Use of Spread Spectrum Techniques in Non-Government Applications", MITRE Corp. Report MTR80W00335, Dec. 1980, p. 6-6 (http://www.mitre.org/work/tech_papers/tech_papers_07/MTR80W335/MTR80W335.pdf)

[8] Most other regulatory agencies with technical jurisdiction also have technical advisory committees to assist them in their regulatory deliberations. While FCC created a Technological Advisory Council in 1998, it has not met since 2006 and it is not clear if it actually still exists, although the FCC web site implies its existence. *See* http://www.fcc.gov/oet/tac/

and overlay issues. The reports conclusions about future civil applications are shown in Figure 1.

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.

In the maritime mobile area, direct sequence spread spectrum signaling is being proposed for emergency signaling via satellite. This concept has been partially field-tested, and could be implemented in the late 1980's. Direct sequence signaling has also been examined for possible use in terrestrial VHF maritime mobile applications, but the well-known vulnerability of direct sequence techniques to nonuniform signal levels (i.e., the "near-far" problem) will work against their realization in any mobile application that does not involve relay from geosynchronous satellites or dynamic control of transmitter powers.*

* However, hybrid techniques involving direct sequence techniques are entirely possible in such applications.

Aside from these better-known potential applications, the use of spread spectrum may be proposed in areas that have not previously received such attention. Near-term applications are likely to involve low-cost techniques like slow frequency hopping, the modification of homodyne sensors to provide a spread spectrum capability, chirp radar or chirp radiolocation systems.

Figure 1: Recommendations of the MITRE report[9]

The later development by Qualcomm of ATPC addressed the "near-far" problem and enabled general land mobile use of this technology. Advances in semiconductor technology rapidly reduced costs and sizes over the next 2-3 decades and enabled consumer products using this technology. Although not mentioned in the major

[9] Scales, *op. cit.,* p. 6-5 to 6-6

conclusions quoted above, the MITRE report also raised for the first time the issue of spread spectrum use in various ISM bands as is shown in Figure 2.

> 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.

Figure 2: MITRE Report introduction of ISM band use for spread spectrum[10]

The discussion on the report reviewed a number of ISM bands: 13.56 MHz ± 6.78 kHz, 27.120 MHz ±150 kHz, 40.680 MHz ± 30 kHz, 915 MHz ± 13MHz, 2.45 GHz ± 50 MHz, 5.8 GHz ± 75 MHz, and 24.125 GHz ± 125 MHz and noted that only the bands at and above 915 MHz had enough bandwidth for interesting spread spectrum applications. The 24 GHz was rather high for affordable technology at the time and also had significant use by police radars, raising the question of possible interference to public safety systems. Thus the MITRE report raised the novel issue of possibly using the ISM bands but did not make any concrete recommendation.

The 1981 Notices – Phase II

After the MITRE report, deliberations within FCC and between FCC and the National Telecommunications and Information Administration (NTIA) continued. NTIA, under delegation of the President's 47 USC §305 authority, is responsible for all spectrum use by federal agencies and, by mutual agreement with FCC, reviews with FCC possible policy changes that might cause federal radio system interference to non-federal users and vice versa.[11] In particular, all the ISM bands being considered had some federal spectrum use in them, so coordination with NTIA was essential.

NTIA has legal responsibility for spectrum use by federal agencies, but in practice *most* of its decisions are made by the Interdepartmental Radio Advisory Committee (IRAC)[12], a consisting of federal employees representing most agencies that are significant users of

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[10] *ibid.,* p. 3-25

[11] The current, 2003, Memorandum of Understanding between FCC and NTIA on coordination is available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-230835A2.pdf . The document that was in place at the time of these discussions was basically similar.

[12] *See* http://www.ntia.doc.gov/osmhome/irac.html

radio spectrum. One reason for this arrangement is that, since the former White House Office of Telecommunications (was transformed into NTIA in two steps during the Nixon and early Carter Administrations, the Assistant Secretary of Commerce who heads NTIA really does not have the "political horsepower" in Washington to direct major agencies, like the Pentagon and the FBI, on how to manage their radio systems. So the spectrum-using agencies meet in IRAC and its subcommittees to compile their requirements and trade spectrum among themselves. It is an arrangement not unlike the "inmates running the asylum". Only in exceptional cases does the NTIA leadership try to overrule the IRAC consensus, although in theory it has the legal power to do so.

In the FCC/NTIA/IRAC coordination efforts on spread spectrum, the representative of the National Security Agency (NSA) repeatedly urged caution, not on the radio interference issues that were in the FCC/NTIA agreement on coordination, but on the basic issue of civil (as opposed to military) use of spread spectrum. (However, it was never clear whether the positions stated by the NSA representative were those of senior NSA management or low level staffers acting on their own.) While the basic details of spread spectrum were available in a variety of esoteric journal articles, only in 1976 was an overview of the technology published in a commercial book.[13] When I first got involved in spread spectrum technology during my employment with IDA, the only comprehensive discussion was in a textbook-like classified report, complete with questions at the end of each chapter, that NSA had commissioned from Sylvania Electronic Systems. It became clear that some individuals at NSA hoped to keep spread spectrum off the commercial market for fear that foreign military use of the technology would complicate NSA's signal intelligence responsibility. On the other hand, given the basic availability of information on the topic, it was inevitable that commercial use would come.

Based on my work with military spread spectrum systems, I tried repeatedly in IRAC meetings to make the point that military spread spectrum technology was fundamentally different than civil systems. That is, military systems had very complex technology to assure that the enemy does not find and exploit a weak link in the signal that destroys spread spectrum's basic military goals of resistance to jamming or covertness. It is this resistance that makes military spread spectrum equipment very expensive. Further, this resistance involves design details that had not been published in the open literature and were unlikely to be. Civil systems did not need, and could not, afford this complexity, as the risk of their diversion to foreign military use was small.

The turning point in the dialog with NSA came at a major conference of their community held at their headquarters in 1983 on spread spectrum issues. With mixed feelings, I accepted an invitation to speak on FCC proposals for civil spread spectrum, uncertain about how hostile the audience would be in the heart of the intelligence community. Fortunately, I was introduced by a very senior NSA official who made an interesting observation in his introductory remarks: He pointed out that his wife had just bought a new car with an electronically tuned AM/FM radio with scanning capability (novel at the

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13 R. Dixon, *Spread Spectrum Systems*, Wiley, 1976

time, but common today). He pointed out that the tuning capability of this consumer receiver was similar to the receiver technology that was needed for a frequency hopping spread spectrum system, and speculated that the spread spectrum Pandora's box may already have been opened and that shutting it was probably futile. This comment marked a turning point in discussions with NSA and the other military members of IRAC, and basic opposition to civil spread spectrum started melting away.

My staff at FCC started drafting a Notice of Inquiry (NOI) on spread spectrum technology. Michael Kennedy, who had joined my staff from the Commission's Field Operations Bureau, was the primary author of the NOI. This was his first work on the spectrum policy side of the FCC, and he later went on to a distinguished career for Motorola in spectrum policy issues. The NOI was approved by the Commission at its meeting on June 30, 1981.[14] After the 1980 presidential election, Chairman Ferris, who had strongly supported the initial deliberations, had left. By the time of the Commission consideration, Mark Fowler had become chairman. Although Chairman Fowler rejected some of the policies of Chairman Ferris, in this area, the "Reagan Revolution" was consistent with the Carter-era deregulatory agenda spearheaded by Alfred Kahn. Removing barriers to innovation easily won initial support from the new team on the Commission's 8th floor.

Figure 3: Presentation of spread spectrum NOI at June 30, 1981 Commission meetin

The NOI stated that it was:

> "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

[14] Notice of Inquiry, Docket 81-413, 87 F.C.C.2d 876 (http://www.marcus-spectrum.com/documents/SpreadSpectrumNOI.pdf) Video of the Commission's discussions of the NOI is available at http://www.marcus-spectrum.com/FCCNOIJune81.mov

> used to measure these parameters, and identify technical standards necessary to insure operation on a minimum interference basis."[15]

While this action ultimately led to a major expansion of unlicensed spectrum use and is best known for its impact on wireless LANs, neither of these issues were mentioned at this point. Rather, the focus was on finding a technical framework for permitting the use of spread spectrum without interfering with other users, while at the same time not specifically requiring the use of this technology. The issue of ISM band use, first queued up by the MITRE report, however was included.

Unlicensed rules for spectrum have been in the FCC Rules since the late 1930s.[16] The basic logic for permitting unlicensed use at the time was stated clearly by FCC Chief Engineering Ewell Jett in a 1939 hearing:

> "What we are concerned with immediately is the problem of interference. If certain low power devices can be used without interfering with radio communications, there would appear to be no engineering reason for suppressing their use."[17]

Legend has it that the original unlicensed device was a "couch potato"-like remote control for radio receivers. But since this humble start, the Commission's rules have expanded in response to petitions to myriad provisions for narrowly defined devices for specific purposes (e.g. cordless telephones, home security systems) in specified bands with specified modulations and powers. New uses and new technology almost always required a petition and lengthy rulemaking. This was a situation that needed reform, but such reform was not a stated goal of the NOI. Indeed, the word "unlicensed" does not even appear in the NOI.

The NOI discussed the basic technical concept of spread spectrum, raised the possibility of CDMA and "overlay" use of the technology, and discussed possible measurement techniques that could be a basis of technical rules. This was followed by a list of 18 questions. In retrospect, the most interesting questions were:

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[15] NOI at para. 3

[16] K. Carter, A, Lahjouji, and N. McNeil, "Unlicensed and Unshackled: A Joint OSP-OET White Paper On Unlicensed Devices and Their Regulatory Issues" Federal Communications Commission, OSP Working Paper 39, May 2003 (http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-234741A1.pdf) ; J. Snider, "Spectrum Policy Wonderland: A Critique of Conventional Property Rights and Commons Theory in a World of Low Power Wireless Devices", Telecommunications Policy Research Conference, Sept. 2006 (web.si.umich.edu/tprc/papers/2006/644/06-09-30--TPRC--SpectrumPolicyWonderland.pdf)

[17] Informal Hearing Before the Chief Engineer In the Matter of Proposed Rules and Regulations Governing the Operation of Low Power Radio Frequency Devices, FCC Docket No. 5335, September 19, 1938, p. 5.

> (m) Which ISM bands might be suitable for spread spectrum overlay? How detrimental would this be to existing users? What sort of services could use ISM band overlay?
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> (n) Would the increased cost of spread spectrum equipment prohibit its acceptance by users? How much would equipment cost be expected to increase?

At the time, spread spectrum was an exotic, primarily military technology and there were serious doubts about its long term costs. While Moore's Law had been known since 1965, it was not clear that it applied to radio technology since these systems were basically analog then. Thus the cost question seemed appropriate.

At the same time, the NOI was adopted a Notice of Proposed Rulemaking (NPRM) in Docket 81-414 to amend the Part 97 Amateur Radio Service rules to permit use of spread spectrum technology by amateur radio operators (hams).[18] It seemed possible that radio hams might be interested in experimenting with this technology and facilitating its commercial introduction on simplified forms, just as they had played a key role in the introduction of single sideband technology in the shortwave bands. Ultimately, it turned out that this was good public relations and fence mending between the Commission and the amateur radio community, but had little net impact.

The Docket 81-413 NOI received support from Hewlett-Packard Corp.[19] and a few individuals, but was roundly criticized by many parties, ranging from broadcast interests to land mobile radio interests. While the major mobile radio equipment manufacturer at the time indicated in off-the-record discussions that it was vehemently opposed to all commercial use of spread spectrum, it never filed public comments opposing the proceeding. Rather it apparently supported land mobile user associations that in turn filed statements in opposition to the use of spread spectrum.

The FCC staff described the comments as follows:

> It was felt that there are many useful communications applications which could be achieved with spread spectrum techniques that could not be satisfactorily developed with any other technology. However, many had reservations about the particular implementation of spread spectrum systems and expressed concern over the potential for interference with existing communications systems. Because the technology is so new, many urged the Commission to **proceed slowly** with its implementation until we have had successful operating experience with these systems, including the identification and measurement of spread spectrum signals and their interference potential. There was particular concern among some parties that regular communications might be interrupted and the Commission might not be able to detect the source of the interference. (Emphasis added)
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[18] *Notice of Inquiry and Proposed Rulemaking*, Docket 81-414, 87 F.C.C.2d 972

[19] This was years before HP's divestiture of all but its information technology product lines in 1999. The HP Laboratory group that was dealing with this issue is now part of Agilent Corp.

> The topic that caused the most concern was the potential interference that spread spectrum systems might cause to existing services. Some concern was also expressed about the possibility of spread spectrum systems interfering with each other. GE felt that the interference problems presented by spread spectrum systems may be so great as to preclude their successful implementation in the land mobile services. Because of this, they thought that spread spectrum systems should not be authorized in mobile services but should be confined to the FIXED services.
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> Both GE and RCA objected to authorizing spread spectrum systems in the Industrial, Scientific and Medical (ISM) bands because m any Part 15, low power consumer devices, such as home security devices and video disc systems, have already been authorized to operate in some of the bands. Not only were they concerned that spread spectrum systems operating in the ISM bands might cause interference to these devices, they also feared that any interference could lead to restrictions on the ISM bands for all Part 15 devices. Although RCA's objections were limited to the ISM bands below 1000 MHz, GE did not qualify its objections. All other parties responding to this issue felt that spread spectrum systems should be authorized in the ISM bands. [20]

Sensing the lack of interest and support for spread spectrum, I looked for parties that might be interested in commenting. In April 1982, I was invited to give a talk on the FCC's views of spread spectrum at a small IEEE Information Theory Society workshop held at a Wickenburg, Arizona dude ranch. This workshop was attended by many of the prominent researchers at the time in information theory and communications theory. At an after-dinner rump session, I challenged the attendees issue of moving spread spectrum from academic journal articles to practical civil use would require that the intellectual backers of the technology participate in the ongoing FCC rulemaking and address some of the issues that were being raised. Ultimately, both the IEEE Information Theory Society Communications Theory Committee and the IEEE-USA Committee of Communications and Information Policy filed comments advocating the positive features of spread spectrum.

In retrospect, the 1981 NOI and the subsequent NPRM, discussed below, raised the NIMBY ("not in my backyard issue") to many parties in its discussion of overlays. Virtually all existing licensees were threatened by the concept of overlays by imagining a worst-case scenario where the overlay user was inches away from the "victim" receiver. Similarly, there was fear of noise floor aggregation from the affect of multiple overlay devices. Given that there was no strong proponent for overlays and that there was broad opposition, it was inevitable that this the proposed overlays would never happen until a well-funded proponent was prepared to battle the FCC on the issue. Such a proponent did not emerge until the ".com economy" made speculative funding of such new technologies possible in the late 1990s, and Time Domain, Inc. and Xtreme Spectrum, Inc. engaged the vested interests in spectrum in a multimillion-dollar, Herculean battle in Docket 98-153. This battle resulted in new rules for ultrawideband overlays. However,

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[20] Further Notice of Inquiry and Notice of Proposed Rulemaking, Docket 81-413, 98 F.C.C.2d 380 at para. 8,13-14

(http://www.marcusspectrum.com/documents/SpreadSpectrumFNOINPRM.pdf) At this time both GE and RCA were manufacturers of land mobile equipment and other radio equipment, although both would exit these areas shortly thereafter.

it was a pyrrhic victory that also resulted in the bankruptcy of both firms and the loss of most, if not all, of their original investors' equity.

Shortly after the adoption of the NOI, Chairman Fowler decided to ask Dr. Lukasik to leave FCC. Such replacement of top managers by an incoming chairman was not unusual at the time and has become much more common since then. Dr. Lukasik was replaced by Dr. Robert Powers, a career civil servant who had been at FCC for a few years and had previously worked in the Commerce Department. It would not be until 18 years later and the arrival of Dale Hatfield in 1999 that the technical part of FCC would have a leader who had the direct support of and access to the FCC chairman.

1984 Notice of Proposed Rulemaking – Phase III

Based on the comments to the NOI, the OST staff tried to draft proposals for specific rule that could enable some commercial use of spread spectrum and yet be pragmatic enough to get the support of a majority of commissioners. It was noted that use of the ISM bands had raised relatively few concerns compared to overlays, yet with hindsight the NPRM failed to grasp this. It proposed low power overlays on an unlicensed basis on **all** bands above 70 MHz, except 28 specific bands to which NTIA refused to agree during interagency coordination. Years later these enumerated bands would become the basis for the restricted bands now listed in §15.205.

The Commission adopted the NPRM on April 26, 1984 on circulation, meaning that it was not discussed at a public Commission meeting. At the time, the commissioners did not consider it important enough to require a discussion in public. The core of the NPRM was in the following paragraphs:

> "It appears that most low power communication devices, currently authorized under Part 15 of our Rules and Regulations, could be considered as potential candidates for spread spectrum. As the staff at the Commission's Laurel Laboratory facility has considerable experience in measuring the emissions from Part 15 devices, the authorization of spread spectrum devices under this section of the Rules is attractive, since the expertise of the Laboratory staff could be drawn upon in establishing measurement standards for these devices and monitoring their emissions. However, most of the measurements at the Laboratory have been made on narrowband transmitting systems. Consequently, we will also have to rely on comments and help from outside the Commission in developing meaningful measurement standards for broadband systems. We would like to draw upon industry's knowledge and resources in this area and invite their comments on the development of such broadband measurement standards.
>
> The authorization of spread spectrum systems under Part 15 of the Rules is attractive from another point of view. With the exception of frequency hopping systems, spread spectrum devices require continuous bands of spectrum in which to operate. But since Part 15 low power communication devices are authorized to operate on all frequencies above 70 MHz, subject to certain restrictions, spread spectrum systems authorized under this Part of the Rules would have access to this broad continuous area of spectrum. This essentially unlimited amount of spectrum is therefore important to spread spectrum use. Also, **authorization of spread spectrum devices under Part 15 would allow considerable experimentation to be done on devices such as wireless microphones and wireless data terminals without Commission regulations restricting their development.** At the same time, the Commission might be spared the immediate need to allocate additional spectrum

> space for these services and for other requested services such as cordless telephones. Many specific problem areas, such as those pointed out by Lucasfilm Ltd., could perhaps also be eliminated by Part 15 spread spectrum authorization. The use of spread spectrum in existing types of Part 15 devices, such as cordless phones and garage door openers, might increase their interference rejection capability while decreasing their potential interference to other systems and improving their privacy.
>
> **The authorization of spread spectrum systems under Part 15 of the Rules and Regulations would be unrestrictive and unregulatory in nature, since devices operating under Part 15 do not have to be licensed and users do not face eligibility requirements, content regulation, or coordination requirements. This would allow the forces of the marketplace to drive the implementation of this new technology, unhampered by regulations other than those needed to prevent harmful interference to licensed systems.** Because of this, we are proposing to allow spread spectrum usage, under Part 15 of our Rules, for all low power communication devices which transmit or receive information on frequencies on or above 70 MHz." (Emphasis added.)[21]

Thus, unlicensed use was proposed and it was recognized that it might be valuable for future "wireless data terminals" and that "authorization of spread spectrum devices under Part 15 would allow considerable experimentation to be done on devices such as … wireless data terminals without (detailed) Commission regulations restricting their development". Unfortunately, the staff's myopia about the acceptability of overlays in that era made a confrontation with existing licensees inevitable, in addition to fueling the looming confrontation with the major manufacturer that sought to block all commercial use of spread spectrum at the time.

The NPRM also proposed use of spread spectrum by police licensees only for "communications in connection with physical surveillance, stakeouts, raids, and other such activities."[22] This provision and the mention of cordless phone use unexpectedly ended up resulting in new opponents to the rulemaking. At the time, both the police community and the cordless phone users were seeking access to new spectrum for expanded use in other FCC proceedings. Under the "command and control" style of spectrum management in place at the time, these communities were expected to show growing demand and a lack of other technical alternatives. Both groups suspected that the mention of their type of spectrum use in the NPRM was an insidious plot by FCC to deny them the spectrum they had requested, even though this was never considered, and they therefore joined the legions of opponents to the rulemaking. The cordless phone manufacturers ultimately received the additional 47 MHz spectrum they were requesting, although it is interesting to note that, at the writing of this paper, most cordless phones sold in the US are actually spread spectrum units authorized under the rules that were so controversial.

The police community has continued to get additional spectrum since the time of these deliberations, although the key request at the time for increased sharing of UHF-TV broadcast spectrum was derailed a few years later, on the eve of its final adoption, by

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[21] *Ibid.* at para. 16-18

[22] *ibid.* at proposed §90.19 (g)(3)

broadcast interests pressuring the Commission for what later became DTV.[23] The spread spectrum issue never affected either police or cordless phone spectrum deliberations despite the proponents' fears.

1985 Decision – Phase IV

For the reasons discussed above, the 1984 NPRM did nothing to decrease the controversy of proposed spread spectrum use. To Dr. Powers and me, it felt that we were under siege as we tried to implement the general philosophy that had been initially advocated by Chairman Ferris and was now advocated by Chairman Fowler. In retrospect, the increasing isolation of our office from the inner deliberations of the Chairman's Office resulted in an insensitivity to how much our pursuit of this issue was alienating others on the FCC staff who were more concerned about the thoughts of major industry players than to more abstract deregulatory philosophy.

I was given an ultimatum by my supervisor to wind up the rulemaking by Spring 1985 regardless of what the outcome was, because the "8th floor" was getting annoyed with the ongoing controversy. It was around this time that my staff and I finally grasped that, by combining the ISM band concept, first proposed in the MITRE report, and the unlicensed concept proposed in the NPRM, we could provide an initial path for market access for spread spectrum and sidestep most of the controversy. The NPRM had proposed power limits consistent with "all bands above 70 MHz" and these powers were rather low because they were based on the assumption of overlays.

We decided to focus on the 900, 2400, and 5700 MHz ISM bands because they had the necessary bandwidth for interesting spread spectrum systems and did not have police radars like the 24 GHz band did. We then went back to NTIA, since these bands were shared with federal government users, and asked how much power the federal systems could tolerate from spread spectrum users in these bands. After a lot of internal deliberations, NTIA and IRAC came up with an upper limit of 7 W. It was never clear how they reached this number, but after thinking it over within FCC, we decided to reduce the number to 1 W.

I have been asked many times since then where this number came from. First, it was less than the 7 W limit NTIA had decided on. But more importantly, we were thinking about short range systems within or around a home or office, such as cordless phones, wireless microphones, or "wireless data terminals," and it was clear that 1 W was more than enough power to perform this function. Further, with 7 W you would be getting into the longer-range functionality traditionally associated with Part 90 systems, and the rules would be a threat to the land mobile establishment. At the same time, we were independently pursuing policy deliberations on RF safety issues that were ultimately

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[23] J. Brinkley, *Defining Vision: How Broadcasters Lured the Government into Inciting a Revolution in Television*, Harvest Books, 1998

implemented in §§1.1307,1310. We did not fully realize then that 1 W was about the maximum power that a handheld or near-body device could transmit with a high duty factor and still comply with the RF safety limits that the Commission was adopting. Thus a higher limit, in retrospect, would not have been practical, and most unlicensed spread spectrum devices are actually less than 1 W anyway for a variety of practical reasons, including battery considerations and RF safety.

Figure 4: Presentation of the spread spectrum Report and Order at the May 9, 1985 Commission meeting (Dr. Powers on the right of the picture)

On May 9, 1985, the Commission met and approved at a public meeting the Report and Order (R&O) authorizing unlicensed use of spread spectrum.[24] The R&O included a section authorizing limited police use of spread spectrum and a parallel R&O was adopted permitting amateur radio use of spread spectrum.[25] The R&O noted that:

> "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."[26]

But since the R&O's unlicensed use focused on ISM bands, this analysis was no longer relevant. The actual spread spectrum rules that were initially adopted were as follows:

> "**§15.126 Operation of spread spectrum systems.**
>
> Spread spectrum systems may be operated in the 902-928 MHz, 2400-2483.5 MHz and 5725-5850 MHz frequency bands subject to the following conditions:
>
> (a) They may transmit within these bands with a maximum peak output power of 1 watt.

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[24] First Report and Order, Docket 81-413, 101 F.C.C.2d 419 (http://www.marcus-spectrum.com/documents/81413RO.txt)

[25] Police and amateur radio use of spread spectrum never became significant and are, in effect, an obscure dead end of these deliberations.

[26] *R&O* at para. 10

> (b) RF output power outside these bands over any 100 kHz bandwidth must be 20 dB below that in any 100 kHz bandwidth within the band which contains the highest level of the desired power. The range of frequency measurements shall extend from the lowest frequency generated in the device (or 100 MHz whichever is lower) up to a frequency which is 5 times the center frequency of the band in which the device is operating.
>
> (c) They will be operated on a noninterference basis to any other operations which are authorized the use of these bands under other Parts of the Rules. They must not cause harmful interference to these operations and must accept any interference which these systems may cause to their own operations.
>
> (d) For frequency hopping systems, at least 75 hopping frequencies, separated by at least 25 kHz, shall be used, and the average time of occupancy on any frequency shall not be greater than four-tenths of one second within a 30- second period. The maximum bandwidth of the hopping channel is 25 kHz. For direct sequence systems, the 6 dB bandwidth must be at least 500 kHz.
>
> (e) If the device is to be operated from public utility lines, the potential of the RF signal fed back into the power lines shall not exceed 250 microvolts at any frequency between 450 kHz and 30 MHz.
>
> Note.--Spread spectrum systems using the 902-928 MHz, 2400-2500 MHz and 5725- 5850 MHz bands should be cautioned that they are sharing these bands on a noninterference basis with systems supporting critical government requirements that have been allocated the usage of these bands on a primary basis. Many of these systems are airborne radiolocation systems that emit a high EIRP which can cause harmful interference to other users. For further information about these systems, write to: Director, Office of Plans and Policy, U.S. Department of Commerce, National Telecommunications and Information Administration, Room 4096, Washington, D.C. 20230. Also, future investigations of the effect of spread spectrum interference to Government operations in the 902-928 MHz band may require a future decrease in the power limits."

The key feature of these rules is what they do not contain. They do not limit the use of this unlicensed spectrum to any specific class of use or users. As the NPRM had stated, they:

> (W)ould allow the forces of the marketplace to drive the implementation of this new technology, unhampered by regulations other than those needed to prevent harmful interference to licensed systems.

In the 1981-85 period when these rules were drafted, wireless LANs were not a common topic of discussion. Indeed, Ethernet other LAN installations were rare outside technical organizations and unheard of in homes. The deliberations had raised the possibility of "wireless data terminals" as an example, but did not specifically "tilt" in favor of this application in the resulting rules. The Carter and Reagan era faith in deregulation laid the foundation for the future development of a variety of products without the need for government action. This probably leveled the playing field for investors, and for internal R&D managers within corporations, because successful new technology would have market access without waiting for unpredictable regulatory action.

These rules were later recodified as §15.247 in a major reorganization of Part 15 in 1989. They have been added to several times at specific requests from industry seeking either to permit new products or to restrict the products of competitors. It is ironic that the amendments to the spread spectrum rules made in Docket 89-354[27] (which I had nothing to do with) four years after their initial adoption almost had a negative impact on the birth of Wi-Fi. These amendments were made in response to the complaints of some manufacturers that some early commercial spread spectrum systems with no real processing gain were unfairly competing with them. Internal FCC questions about whether 802.11b complied with the amended rules almost had the effect of not permitting use of the 802.11b standard. For various reasons, FCC never formally addressed this issue and the issue became moot with the later revisions of the rules that enabled 802.11g.

Aftermath

In some ways, the successful adoption of the 1985 rules was a personal Pyrrhic victory. In pressing for the rules that seemed to be consistent with the Commission's overall policy goals, I was not adequately sensitive to the growing levels of opposition and the concerns of other FCC elements. As a result of this action, as well as actions Dr. Powers and I had taken in other proceedings to raise technical issues that were not always welcome, we gradually drifted out of the mainstream of Commission leadership. Shortly after the adoption of the R&O, Dr. Powers was summoned to the Chairman's Office and told that they were not happy with his "management style" and that he should leave. He was ultimately allowed to take early retirement. Our office was reorganized, and both my position and that of one of Dr. Powers' deputies were eliminated in the first FCC "reduction in force"/RIF in 8 years and the last one to occur for another 7 years. (Both of these other RIFs were much larger and dealt with major program changes.)

Such a RIF of one's SES position generally results in either a demotion or dismissal. For the performance period that ended September 1985, I received the lowest FCC Senior Executive Service performance level rating since the SES system was adopted in 1979. (This action was probably part of the effort to dismiss me since under civil service rules I could "bump" someone with a lower performance rating and take *their* job if my job was eliminated.)

Prior to the FCC approval of the R&O, I had submitted a paper on the FCC spread spectrum policy deliberations for the December 1985 IEEE GLOBECOM conference.[28] As time approached for the meeting, FCC leadership thought it would be best to have as little attention on the topic as possible. They refused to send me or anyone else to give the paper and talk about the new rules and at one point even tried to prevent me from

[27] Report and Order, Docket 89-354, 5 FCC Rcd. 4123 (http://www.marcus-spectrum.com/documents/89-354.pdf)

[28] M. Marcus, "Recent FCC Regulatory Decisions on Civil Uses of Spread Spectrum", *Proc. IEEE Global telecomm. Conf. 1985,* p. 504-506

taking annual leave and going at my own expense. I ultimately got permission to go at my own expense but without using annual leave.

Finally in November 1985 while my position elimination was pending I was transferred from the position of the chief of a division with 35 staffers to an undefined job in the Commission's Field Operations Bureau sharing an office with 4 other people. Apparently my efforts to create these rules were not fully appreciated! (After I hired a lawyer and challenged the RIF procedure used, FCC management dropped the RIF without acknowledging there were many procedural irregularities and I was left in FOB. Although the move took me away from the spectrum policy area where I felt I could make my greatest contributions, I ultimately was able to get involved in several interesting issues in FOB, including the identification of the signals of malicious jammers of safety-related and other transmissions.[29] The other deputy involved in the RIF ultimately also found a new home within FCC.)

While in internal exile from the FCC policy community, I was invited to write an article for *IEEE Communications Magazine* on radio LANS. The article was based in part of the 1985 GLOBECOM paper and was published in July 7, 1987. Part of the article is shown in Figure 5:[30]

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[29] While the investigations and successful criminal prosecutions of the 1987 "Captain Midnight" and 1988 Playboy satellite jamming cases may not have been the most profound work I was involved with at FCC, they certainly raised novel issues and were an interesting diversion from policy work.

[30] M. Marcus, "Regulatory policy considerations for radio local area networks", *IEEE Communications Magazine*, Vol. 25, No. 7, (Jul 1987) p. 95 - 99

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 equipment is rare in most areas with the exception of the ubiquitous consumer microwave oven. Fortunately, safety regulations severely limits the external emissions from such consumer equipment.

Figure 5: July 1987 *IEEE Communications Magazine* article excerpt

It is interesting to note that radio LANS were explicitly discussed by this point. So clearly interest in this application had become more specific than the more vague term of "wireless data terminals" that was used in the R&O. As discussed below, the first wireless LAN was actually on the market by the time this article appeared in print.

Slowly manufacturers noticed the new rules and became interested in them. The first marketed equipment was from a startup Canadian firm, Telesystems SLW[31]. It was a 900

[31] Telesystems was acquired by Telxon, which was acquired by Symbol Technologies, which was acquired by Motorola.

Figure 5: First commercial unlicensed spread spectrum system: Telesystems ARLAN (shown without separate power supply)

MHz wireless LAN system. The second system was made by an Atlanta area startup, Gambatte, Inc which introduced a specialized radio LAN for the MIDI data format used by musicians. It quickly became popular in the niche market for live performance equipment by top rock artists, and the basic technology is still in use in equipment designed for real time monitoring of radiation exposure of workers in nuclear power plants.

Figure 6 shows the growth of annual approvals of new equipment models under these rules. The initial slow growth turned into a major stream of new models in the late

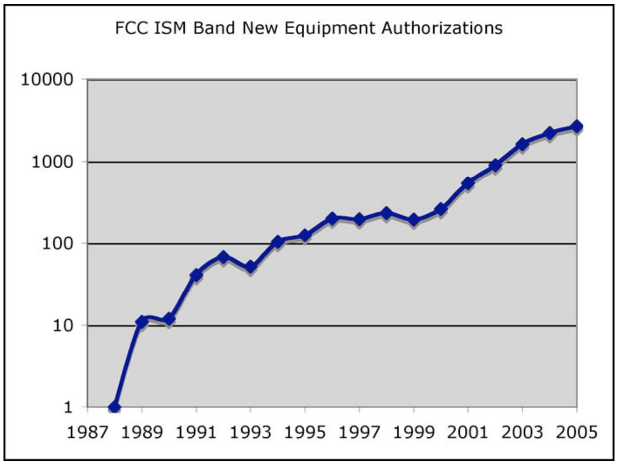

Figure 6: New FCC ISM band equipment authorizations[32]

1990s with the development of the Wi-Fi standards and new components that made high performance cordless phones practical.

Vic Hayes, the former Chair of 802.11, has commented on why these rules were successful:

> • The fact that no end-user license was required
> • The rules provided a whole playfield of inventiveness
> –High data rates were possible and satisfied the data requirement
> • Generous amount of spectrum
> • Frequencies were exactly right for the technology[33]

My personal bureaucratic exile from the FCC's policy community ended in 1994 when Chairman Hundt replaced Dr. Powers' replacement, and I moved back to the Office of Engineering and Technology as Associate Chief for Technology and received a promotion. One of my first projects was to propose and get approval for a new initiative to allow unlicensed use of 60 GHz, Docket 94-124.[34] These products are now known as

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[32] FCC Spectrum Policy Task Force with additional data from FCC website

[33] Presentation of Vic Hayes on "Impact of Spread Spectrum Rules on the Wireless IEEE 802 standards", IEEE 802 meeting, March 16, 2004 (http://www.ieee802.org/802_tutorials/march04/Spread_Spectrum_Perspective_VH.pdf)

[34] http://www.fcc.gov/oet/dockets/et94-124/

Wireless HD.[35] The same year, IEEE-USA awarded me its first Electrotechnology Transfer Award for

> " (P)ioneering work in the conception, drafting, and enactment of the Federal regulations that legalized commercial spread spectrum radio under FCC Part 15, the rules governing unlicensed devices; thus spawning a multimillion dollar, worldwide, wireless industry."[36]

It is ironic that, while this proceeding was initiated to open spectrum access for spread spectrum technology, as wireless LAN speed got higher and higher, the rules had to be and were relaxed to allow other technologies. But by that point, spread spectrum had proven its worth in the commercial market and there was no longer a need to force manufactures to use it in order to gain spectrum access. Applications needing additional robustness from interference or multipath propagation are still free to use spread spectrum, which will decrease the achievable data rates in those cases.

The commercial implementation of CDMA for mobile communications was not explicitly addressed in Docket 81-413. But it is known that Qualcomm was incorporated in July 1985 and there are anecdotal reports that the May 1985 decision was helpful in Qualcomm's initial search for investment capital. In any case, the breakthrough that permitted CDMA in cellular systems came in 1987, when FCC declined to adopt a specific 2G technology standard as it had in 1G, and thus opened the door to multiple standards, including CDMA. I like to think that my policy work in technical deregulation in Dockets 83-114[37] and 85-171[38] was also influential in this decision, but there is no paper trail to show that. But in any case, both the unlicensed systems and cellular use of CDMA showed spread spectrum's viability for civil applications.

Conclusions

The rules adopted in Docket 81-413 had a much greater impact than any of its advocates could ever have imagined at the time. They enabled the development of Wi-Fi, Bluetooth, the majority of cordless phones now sold in the US, and myriad other lesser known niche products. In doing so they created employment and growth for the communications electronics industry but the nature of the unforeseen products produced also changed our daily world[39] and created further economic growth through improving

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35 http://www.wirelesshd.org/company/about.html

36 http://www.ieeeusa.org/volunteers/awards/pastrecipients/electrotechnology.html

37 *Report and Order*, Docket 83-114, 99 FCC 2d 903

38 *Notice of Inquiry and of Proposed Rulemaking*, Docket 85-171, 50 FR 25274

39 The use of many of these products is discussed in Carter, Lahjouji, and McNeil, *op. cit.*

efficiency of our society. Unlicensed systems also became a serious player in our communications infrastructure, although serious disagreements continue as what their role should be in the long term. Without the success of the ISM bands, this discussion would not even be on the table.

These new products did not come from the classic "command and control" approach to spectrum management with its endless delays and preferences for big players. Rather they resulted from deep belief in deregulation, market place forces, and the potential of unleashed technology that was consistent with the regulatory philosophies of the Carter and Reagan Administrations. A key factor was leadership at FCC that had the confidence to look at technical issues on both their merits and public interest considerations; not necessarily picking the most common viewpoint of powerful industry players. A return to such concepts could help enable new breakthroughs in products and services in the future.

Acknowledgements

I would like to acknowledge and thank the many people who worked with me on making these results possible:

• FCC Chairman Charles Ferris - who had the vision to gather a team on technology and policy and challenge them to remove barriers to new technology.

• Stephen Lukasik, former Chief Scientist of FCC - who had the vision to hire me, challenged me to identify the roadblocks to new radio technology, and supported me during the early stages.

• Elliot Maxwell, Dr. Lukasik's deputy - who supported the vision and tried to teach me how Washington really worked.

• Robert Powers, successor of Steve Lukasik as FCC Chief Scientist, who continued to support the initiative even though it proved not to be "career enhancing" for either of us in the short term.

• FCC Chairman Mark Fowler - who recognized that this type of deregulation also fit the Reagan agenda and supported it even though industry was rather negative.

• Arthur Feller, Michael Kennedy, Joseph McNulty, John Reed and Dan Yates - who worked with me to draft the FCC agenda items that implemented the policy.