Chapter 13

Broadcasting and Bandwidth

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Abstract: This chapter will briefly review eight spectrum skirmishes that precede and parallel the 1996 American DTV spectrum decision. We outline the general political and economic contours of these battles and conclude that regulators and lawmakers are at a distinct disadvantage in trying to promote competition, flexibility and a digital paradigm shift against the arrayed forces of incumbent spectrum users. In response we propose some models and concepts loosely drawn from computer science and political economics that might provide a resource to outgunned and well-intended policymakers. The first is the Consumer Value Integral, a theoretical and generalized model of spectrum valuation. One of the conservatizing factors in the spectrum wars is that incumbents can clearly and precisely identify financial gains and potential losses based on current business practices while challengers can identify only potential demand and usage. Furthermore, these valuations struggle to compare public good and private good components. Then drawing on Moore's Law from computer science we speculate on some historical patterns of the next few decades and predict first an increase and then a decline in incumbent-challenger spectrum battles.

1. INTRODUCTION

If you like professional wrestling, you have to love the spectrum wars. Everybody gets dressed up, organizes their entourage and marches with determination down to the FCC. The Chairperson rings a bell and there is

D. Gerbarg (ed.), *The Economics, Technology and Content of Digital TV*

much flailing of arms, grimacing, and groaning about the pain inflicted if even the tiniest sliver of spectrum gets allocated to some upstart challenger. Public safety is endangered, local broadcasting as we know it is threatened, universal service is in jeopardy. The hoopla is worthy of the World Wrestling Federation's finest hour.

If one steps back for a minute, it becomes evident why these particular administrative hearings are prone to such earnest dramaturgy. Spectrum is the ultimate scarce resource -- the underlying rationale behind the use of administrative-political processes rather than market mechanisms in the first place. What better way for incumbents to protect against competition and new entrants? Why not raise a ruckus?

The electromagnetic spectrum is indeed "infused with the public interest"[1]. But spectrum incumbents would have us believe we confront a classic case of a tragedy of the commons.[2] Given the current rules of spectrum allocation, access is highly constrained and limited. It is not that the spectrum is diminished through overuse. It is underutilized and inflexibly utilized because the incumbents of the commons are usually powerfully successful in delaying and complicating the conditions for new entrants. Perhaps the more appropriate portrayal is a tragedy of a privatized commons. The telling metaphor for modeling this dynamic of political economy is more akin to Gresham's Law. Bad money drives out the good because people hoard the most reliably scarce resource. Accordingly, in spectrum games, incumbents always tenaciously hang on to whatever they have and usually wail desperately of further needs. The incentives appear to reinforce hoarding and inefficient usage.[3] This was demonstrated with particular drama in the cross-industry battle between land mobile and television broadcasting between 1968 and 1970 when the seldom used top 84 MHz of the UHF TV band was reallocated to land mobile over the anguished protests of the National Association of Broadcasters.[4]

2. THE SPECTRUM WARS: A BRIEF HISTORY

There is a rich and sophisticated literature on spectrum management. Virtually all of the analysts trace a gradual evolution from fixed and inflexible administrative allocations and allotments to a more flexible market-based system.[5] But progress is slow and uneven. Table 1 outlines a few of the more prominent skirmishes in US regulatory history over the past 75 years.

There are nine cases here including DTV. We begin with the early pandemonium growing out of back-yard AM broadcasters and the crystal-set audience and conclude with case of satellite digital radio which is expected

to launch commercially in the year 2000. The beginning dates of each case are approximate and generally based on the period the case went public rather than the earliest patents and proposals. The end-dates here are determined by the key administrative ruling, and thus the actually commercial use of spectrum often followed several years later. The average length of administrative review is about eight years. This is mostly a product of the strictures of the Administrative Procedures Act of 1948 that dictates FCC processes and the intensity of industry conflict rather than bureaucratic foot-dragging.

Two cases involve wireless telephony. The others concern various forms of broadcasting. The general pattern is one of an entrenched incumbent fending off various competitors.

Even in the first case of AM broadcasting which led to the establishment of the Federal Radio Commission, there were entrenched interests at the battle lines. Early radio was generally conceptualized narrowly as wireless marine communications. The notion of public broadcast information and entertainment evolved only after decades of experimentation. British Marconi tried to dominate the industry by its patents and contracts as early Marconi transmitters and receivers did not interoperate with other manufacturers. Marconi and the US Navy at first resisted broadcasting and it was not until amateurs and hobbyists made AM broadcasting a fait accompli that Commerce Secretary Hoover tried to call the parties together and hammer out a compromise.[6]

If the first case was a Marx Brothers comedy, the second was a noir tragedy. The battle between David Sarnoff of RCA and his former friend Edwin Armstrong, the independent entrepreneurial inventor of technically superior frequency modulation, is indeed a drama worthy of a full-length motion picture. In short, the vested interests of AM broadcasters and the anticipated need for television spectrum successfully conspired to delay and diffuse the transition to FM by about 40 years.[7]

Table 1. The Spectrum Wars

US SPECTRUM CASE	DATES	ALLOCATION	INCUMBENT	CHALLENGER	PROCESS	OUTCOME
AM Radio	1910-1927	535-1705KHz	US Navy, British Marconi	RCA, AT&T, Westinghouse, GE, United Fruit	Chaotic evolution of public-interest based public spectrum management	First come, first served, free license, vague public interest standard
FM Radio	1934-1946	88-108MHz	RCA, et al.	Entrepreneur-inventor Armstrong	Dramatic David-Goliath style battle between established AM broadcasters and inventor	FM long delayed, allocated and then, after further delay, moved to higher frequency
VHF TV	1935-1941	54-88 MHz 174-216 MHz	None	RCA/NBC, Dumont, CBS	Established radio broadcasters move into television broadcasting	Continues first come, first served, free license, vague public interest standard, license renewal routine
UHF TV	1952-1958	470-806MHz	VHF	New entrants, educational institutions	Established TV broadcasters resist competition	Delay, technical problems, much later UHF tuners are improved, required in new sets
DBS Satellite TV	1975-1981	12.2 GHz	Terrestrial TV & cable	New entrants	Established broadcasters and cable industry resist competition	Delay, marketing problems
AMPS Cellular	1968-1982	825-845MHz, 870-890MHz	Wireline telephony and broadcasters	Incumbents & New entrants	Broadcasters and land mobile private resist, PSTN ambivalent	10-15 year delay, duopoly created, dominated by wireline incumbents
PCS Cellular	1991-1997	1850-1990 MHz	Cellular	Incumbents & New entrants	Commission and industry converge on fiction that PCS is new technology rather than competitor to cellular	Complex experiment with auctions, mixed success at generating revenue, encouraging competition, bringing in new or diverse entrants

DTV/HD TV Advanced Television	1988-1997	Reuse of VHF and UHF bands	Terrestrial TV	None	Complex case as high resolution broadcasting becomes digital broadcasting signaling beginning of digital convergence battles	Termed $77B giveaway, Congressional mandate to cede free spectrum powerful broadcast industry is surprisingly uncontroversial
DARS Satellite Radio	1992-1997	S band 2.3GHz	Terrestrial Radio	New entrants	Broadcasters resist competition claiming threat to localism	New entrants granted competitive licenses, broadcasting starts in 2000

The massive allocations to television in the VHF and UHF bands in the 40s and 50s represent an intriguing contrast to the general pattern of incumbent-challenger confrontation, and perhaps an appropriate harbinger of the 1996 DTV spectrum case. These were done deals, prearranged as the radio industry stage-managed the transition to television as networks, executives, engineers and performers all gracefully made the transition to the new medium with the evolved rules of regulation and business practice comfortably in place. TV was radio with pictures and it only seemed natural to the industry, the FCC, and the public that WNBC AM would beget WNBC TV and similarly with the other major stations and affiliates.[8]

The evolution of cellular telephony represents a more traditional incumbent-challenger dynamic. The early rounds of this debate defined cellular as a specialized mobile technology. It has only been in the last decade that wireless local loop and PCS have clarified the prospect that wireless telephony might be a practical and meaningful competitor to wireline provision. Rohlfs, Jackson and Kelly estimate that the decade-long delay in licensing cellular cost the American economy something in the order of $86 Billion in lost consumer benefit. Rohlfs et al. do not blame the Commission or Commissioners but rather the legally dictated process which led to a classic technopolitical stand-off in as interested parties are incented to use every administrative trick available to try to garner a greater piece of the anticipated pie.[9]

In the more recent PCS hearings a curious fiction evolved. The pretence that PCS wireless was sufficiently different in technical character than

cellular that it represent a new technology rather than meaningful competitor was pronounced by all but believed by few. Although this drama has yet to work itself out in the marketplace, the net result has been a modest expansion of incumbent wireline carriers in the cellular business.

The new wrinkle in the 1990s is that after decades of debate and handwringing the Commission was finally empowered by Congress with the right to develop auction procedures for spectrum allotment. The A and B band PCS auctions resulted generally in expanded roles for incumbent players. The Commission found itself litigation as a result of its attempt to exclude incumbents from bidding on frequencies in their franchise areas. The C band auction that explicitly attempted to draw in and sustain new players was by all measures a disaster with 80% of the fee revenues uncollectable, three major bankruptcies and an agency in search of a new system and probably a fresh auction process.

DBS and DARS represent the prospect of new competitors to television and radio from direct satellite transmission. The cast of characters returns to the classic incumbent-challenger shoot-out. Broadcast lobbyists dust off old scripts used to fend off cable competition (television) and 9 kHz spacing (radio). The lobbyists protest that satellites represent significant threats to localism, to free television, and perhaps the American way of life.[10]

What might have been competition from cable and satellite delivery of video turned into a complex scheme of must-carry and compulsory licensing which ultimately reinforces broadcasters' power and influence. The Satellite Home Viewer Act of 1988, for example, gives local broadcasters the right to administratively challenge any DBS viewer in their broadcast area who receives real-time network programming. The law requires the viewer to prove by technically complex and expensive signal strength measurements that they are unable to receive terrestrial broadcast of local network affiliates before they would be legally permitted to seek network programming service from a satellite competitor.[11]

What lessons can we draw from this brief history of skirmishes over potential spectrum innovation? One lesson is simply to behold the conservatizing power of incumbency. The most successful and least controversial cases are those when the incumbents get more of what they already have and those in which new services are seen as complimentary to rather than competitive with existing industries.

Let us assume that the FCC or any equivalently positioned federal or international agency generally defines its job as that of an honest broker. The Commission attempts to maintain a level playing field that arrays current spectrum users who serve legitimate commercial and public interests against challengers who would compete or attempt to serve new commercial and public interests. What factors have tended to tip the field?

2.1 Political power.

The phenomenon of agency capture is well known.[12] It need not be and is not usually manifested as an exercise of simple political influence. It is perhaps better characterized as a shared professional/industry ideology reinforced by the frequent circulation of executives and staff back and forth between the regulators and the regulated. Furthermore, the majority of these spectrum cases have included some form of direct congressional involvement, mandating or constraining agency behavior. The broadcasting and telecommunications lobbies have traditionally been among the most active and well-endowed on Capitol Hill and frequently take their cases public with letter writing and media campaigns. The public relations efforts to protect 'free' television, and localism and to prevent undue taxation and bureaucratic meddling appear to be mildly successful with a semi-attentive public and powerfully successful with a highly attentive collection of elected officials who depend on the broadcast media for paid and free coverage at election time.[13]

2.2 Economic power.

The telecommunications and broadcasting industries are at the forefront of the information age and the long profitable flagship firms, especially AT&T and its offspring, have the economic capacity to acquire access to spectrum through investment if not through direct dealings with the FCC. AT&T's purchase of McCaw Cellular, for example, allowed it instant standing as a major cellular provider. With the partial repeal of ownership limitations in radio and television broadcasting, chain ownership has grown explosively. Although these are open-market transactions, the scale of the economics generally precludes the smaller players.[14]

2.3 Specificity of extant economic interest.

A recurring theme in the cases noted above is the capacity of spectrum incumbents to identify clear and present economic danger in their opposition to proposals for innovation or new service. The FCC's Carroll Doctrine (although no longer in fashion) was an explicit recognition that incumbent profitability and expectation of license renewal were legitimate criteria in Commission deliberations.[15] In contrast, new challengers had to Pdemonstrate technical feasibility, market demand, and the long-term economic viability of their business plans.[16]

2.4 Complexities of public interest obligations.

American telecommunications and broadcasting from the beginning has represented a curious combination of private commercial business practice and a vaguely defined public interest component. In telecom, the notion of universal service obligations (first proposed by Theodore Vail of AT&T, not by the government) provides incumbents a central line of defense against challengers. In broadcasting it is an even more complex and elusive notion of public service. Accordingly, regulators must weigh the costs of innovation to the public service incumbent profitability would otherwise support.[17]

2.5 Limitations of docket-oriented administrative procedures.

The longstanding docket-oriented practice of allocating specific frequencies for specific purposes leads to a disconnected series of narrowly focused, usually dichotomous decisions about optimal spectrum use rather than a more broadly defined spectrum management policy. The division within the FCC into business oriented bureaus and between different agencies including the military and NTIA further fragments the decision process.[18]

3. A CLOSER LOOK AT THE AMERICAN DTV CASE

We began by noting a significant paradigm shift in the management of public electromagnetic spectrum. From the earliest years, the Navy, Commerce Department, Federal Radio and Federal Communications Commissions would assign spectrum with the utmost specificity. The regulators generally specified:

- The frequency range
- The license period
- The geographic range of transmission
- The service definition and associated public interest obligations
- The approved modulation scheme with detailed technical parameters

Because of the expectancy of renewal, licenses once issued acquired the character of private property and could be bought and sold with certain restrictions and routine Commission approval. So although issued for clearly defined time intervals, assignments were viewed as deeded rights in perpetuity.

From the 1960s on, however, academics and policy analysts drew the administrative system into question and suggested diverse alternative means to make the process more responsive, flexible, and market-oriented.[19] The 1991 NTIA magnum opus on spectrum management policy strongly supports the increased use of 'market based principles' and possible 'competitive bidding.' Two strategic positions of the NTIA study are particularly notable. First, as expressed on the report's very first page, the authors' enthusiasm for market principles is limited to new entrants. "This [market] approach would not apply to incumbent licenses or renewals, but only on a prospective basis to the grant of new licenses . . ." Second, they make reference to competitive bidding and possible fees but discretely mention actual auctions only in passing.

Later in the decade, clearly spurred on by potential tax-displacing revenues, the idea of real auctions starts to catch on in the administration, Congress and at the FCC. By the mid 1990s statutory authority to experiment with spectrum auctions is granted to the Commission.

The ultimate culmination of this trend toward liberalization and marketization has been foreseen by Eli Noam.[20] Given the fungibility of digital voice, data and video packets, he anticipates a real-time, automated, open bidding process as potential spectrum users compare the urgency of their bandwidth needs with the going price, literally second by second. He calls it Open Spectrum Access. It can't get any more flexible and market-based than that. It is technically feasible[21]. Is it politically feasible?

Our case in point, DTV, would suggest that it will be some years before the politics of incumbency would permit it. Noam notes in his concluding sentence that it was half a century before the early economic speculations about spectrum auctions became a limited reality. We might expect a similar interval of delay for such a radical idea as OSA.

The legally mandated provision of spectrum without cost to virtually all of the current television broadcasters to provide for parallel transmission of 'advanced television services' in the 1996 Telecommunications Act is, by all measures, a significant step backward in the liberalization of spectrum management. True, it is currently defined as a loan or temporary trade of spectrum to permit the transition to digital TV and the ultimate return of the original analog TV assignments to public control. It may happen at some point, but the history of the process and the negotiations thus far between broadcasters and the Commission counsel caution. The DTV spectrum deal has the following characteristics –

- The assignments require highly specific and redundant service provision.
- The assignments are centrally mandated and automatic.

- The assignments are without fee, bidding or any competitive process.
- The assignments reduce prospects for competition.
- The assignments reduce prospects for innovation.
- The attendant public service obligations are vague and the subject of a complex and politicized advisory process.

The painful ambivalence of the broadcast television industry toward digital and high definition television has been analyzed at length elsewhere.[22] In short, the prospect of a significant investment in new production and transmission equipment paired with no new revenues and unresolved complexities concerning property rights and cable carriage does little to excite the broadcast firms and their stockholders.

Two key elements in the recent history of the legislative history reveal the complex character of the political deal.

First, the spectrum mandate was incorporated in the omnibus 1996 Telecommunications Act. Brinkley characterizes it a 'buried' in a complex bill that had been debated for a decade and was finally moving to a vote. Senator Robert Dole briefly raised attention to the issue in his public statements about the spectrum language and by putting the bill on hold. But his forthcoming presidential campaign would distract him and the bill would move forward to passage in February of 1996. Like the remarkably uncontroversial passage of the Communications Act of 1934, the antecedent of low levels of conflict appears to be the fact that key players were preoccupied with other issues.[23] It was the computer industry that most forcefully challenged the broadcast dominance of the DTV policy process. But their concern was primarily with the issue of computer-compatible progressive scan display technologies, not spectrum assignments. It is impossible to unravel all the complexities of a decade of public and private backroom negotiations but it would appear the computer industry got progressive scan included as part the complex Grand Alliance technical package in return for not drawing attention to the spectrum deal.

Second, the most telling paradox of the DTV policy debate was 'spectrum flexibility' issue. Brinkley tells the story best. First, in 1987, the broadcasters claim that if they are not assigned parallel spectrum for HDTV it would be "the end of local broadcasting as we know it." Then, in growing recognition of the all-cost, no-new-revenue character of the new technology, broadcasters claimed that if they were required to broadcast HDTV on their newly assigned frequencies it would be, again, the end of local broadcasting as we know it. Estimates of the cost of upgrading at the time ran up to $30 million dollars per station. That sounded like it might put some small-market broadcasters out of business. What broadcasters needed, the NAB claimed in 1994 was 'spectrum flexibility' – the capacity to creatively incorporate new revenue producing services including multichannel and pay-TV into the

digital video stream. There was not significant evidence of market demand for sharper pictures. Why not let the market decide the ultimate character of advanced television? It was a bold strategy, perhaps too bold, because the overreach was evident even to a generally supportive congress. When it looked like the spectrum flexibility language might endanger the entire spectrum deal, senior executives sent strongly worded letters to the commission backpedaling on flexibility and requesting that the FCC actually mandate high definition transmission. Trial balloons on multichannel broadcasting by Disney/ABC two years latter received a similarly skeptical and even angry response from Congress. The current language of the 1996 Act permits technical flexibility but if broadcasters derive new revenues, there are prospects of unspecified fees for what would have otherwise been free spectrum. Innovation is permitted, but the incentives are distorted and new entry in the VHF and UHF bands precluded, probably for decades.

Combined with the very mixed success of the Commission's PCS auctions, the progression to liberalized, flexible and market-based spectrum management has been significantly complicated by the events of the last few years.

4. THE CONSUMER VALUE INTEGRAL

For advocates of spectrum liberalization, however, political realism need not yield to pessimism. The prospects of new unlicensed, low and adaptive power applications, transmission and multiplexing efficiencies and the increased viability of higher frequency applications dictate that the spectrum wars will continue. As in professional wrestling, the players show remarkable stamina and the game continues with seemingly infinite variations on a basic theme. This chapter concludes with some speculative models for research and analysis that might stimulate further debate and experimentation.

Our starting point is the inherent asymmetry of the incumbent-challenger conflict. Incumbents have real dollars at stake, and are quick to draw that to the attention of federal policymakers. Challengers have mostly dreams. The key to the puzzle, and long a focal point for researchers' attention, is the difficult task of assessing the value of spectrum.

The authors of the NTIA report get right to the point. "Estimating a dollar value for the entire radio spectrum now in use is extremely difficult, if not impossible."[24] Yet they go on to derive 1991 estimates of the value of the American broadcast spectrum conservatively at $12 billion and urban

cellular telephony at $60-100 billion. Published estimates of the value of the DTV spectrum deal run from $7 billion to $70 billion.

The problem, of course, is that these estimates are made by players who have vested interests in exaggerating or minimizing value, not unlike the centuries old and ritualized exchange between buyer and seller in the bazaar. But what if independent researchers engage the task seriously, taking advantage of growing evidence from the increasingly active license marketplace and actual spectrum auctions could provide for real progress.

So far, the rules of the game for spectrum valuation follow the tradition of strict service definition assignments. The much smaller bandwidth assigned to cellular is worth more than AM, FM, VHF and UHF for broadcasting, because the capacity to derive revenues for telephony per unit bandwidth greatly exceed commercial broadcasting. But in the spirit of Noam's Open Spectrum Access, and the parallel Open Communications Infrastructure initiative[25] -- in digital communications, ultimately, a bit is a bit. The capacity to charge differentially for voice bits and data or video bits will evaporate.[26] All the incumbents in the high-value domains will resist convergence and try to maintain traditional pricing as long a possible. But the good news here is that there are powerful incumbents in the lower and medium value domains that will be incented to compete and blur traditional service definition boundaries. Good news indeed. Professional wrestling. A battle of powerful incumbents versus powerful incumbents.

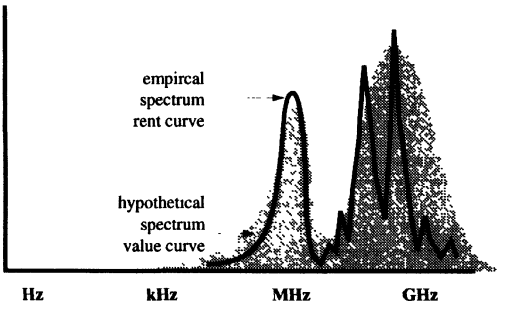

Figure 1. Consumer Value Integral

The idea of the Consumer Value Integral is introduced to spur attention to these issues. We plot the value of spectrum per unit bandwidth as a function of frequency. The height of the curve at a given point represents the potential consumer welfare. The difference between the theoretical maximum value and the actual market value represents, generally, suboptimality of spectrum management. The term integral is used to draw

attention to the possible maximization of the total area under the curve, the greatest total consumer welfare.

We note first the fundamental laws of physics and radio propagation that make broad frequencies ranges differentially valuable. The very low frequencies penetrate barriers most successfully (thus, for example, the specialized use of these frequencies for communication with submarines.) Medium range frequencies bounce off the ionosphere and thus somewhat unreliably travel longer distances (as in international short wave broadcasting) The highest frequencies neither penetrate nor bounce, and are especially subject to rain and weather conditions so are most appropriate for line-of-sight and satellite applications.

Because for all but a limited number of applications the value of spectrum is in its ability to facilitate local communications, the Consumer Value Integral takes the form of a bimodal curve. There is one minor peak in the LF-MF range, and the major peak spanning the VHF, UHF and EHF ranges. The trough in the curve is centered in the most consistently reliable range of the HF spectrum, in the 3-30 MHz range. For most applications, the possibility of interference from low-power transmitters thousands of miles away is a distinct disadvantage. Even among those applications requiring long-range wireless communications, microwave satellite technologies are replacing HF ionospheric propagation as the medium of choice.

The hypothetical value curve is continuous, since the physics of wave propagation varies slowly with frequency. In contrast, the empirically derivable spectrum rent curve would result from the superposition of legal, regulatory and institutional constraints on top of the hypothetical value curve. Over most of the spectrum, it is likely that man-made constraints have inhibited the realization of the value of spectrum. It is also likely that a few well-placed spectrum allocations have benefited from the inefficient use of neighboring spectrum intervals, thus allowing windfall rents (as is apparently the case for the broadcasting and cellular telephone industries.)

The valuation of spectrum is difficult but it is not impossible. Systematic research on valuation and long range spectrum management could serve the industry, the policymakers and the public well and help level the playing field between spectrum incumbents and challengers.

5. MOORE'S LAW AND SPECTRUM INNOVATION

It is the press of technical innovation that inspires us now to move beyond traditional block spectrum allocations for narrowly defined service definitions. Flexibility, the use of market mechanisms, and spectrum sharing

is motivated and advanced among others by the following technical developments:

- The movement from analog to digital transmission
- Interoperability derived from digital transmission
- Declining cost in transmission and reception
- Increasingly efficient modulation techniques
- Increasing viability in the use of higher frequencies
- Improved antenna design
- Improved satellite technologies
- Renewed attention to spread spectrum applications
- Cellular/geographic-reuse and adaptive power technologies

In addition, non-spectrum technologies like advanced work on optical fiber transmission will lead to an increasingly healthy competition between wireline and wireless for commercial and residential communication. One can imagine a "five-pipe" scenario of interoperable digital broadband transmission to the home.

1. Telephone twisted pair evolves into optical fiber to the home
2. Cable television evolves from coax to fiber
3. Power companies or other entrepreneurs provide fiber service
4. Satellite-based spectrum service, one-way broadband, two-way narrowband
5. Terrestrial broadband and narrowband service

It is the fifth category that draws our attention. On the telephonic side there is intense interest in wireless local loop as a potential competitive technology that breaks the scale-economy based last mile logjam. On the television side it is the high frequency LMDS spectrum battle, which may well end up including telephonic players as well.

In the late 1990s there is much speculation on the troublesome last-mile problem. Industries that were once highly profitable near-monopolies in providing telephone, data, radio and television service to the home recognize the coming digital competition.[27] They jockey for position. It may well be that five broadband pipes in competition will generate disappointing revenues for the carriers. Once one or two fiber lines are in place, is it reasonable to believe that a terrestrial spectrum pipe is worth battling for? That is a question for the entrepreneurs. But from a public policy standpoint, the spectrum pipe offers a very special advantage in maintaining competitive markets. Using cellular technologies, spectrum overcomes the wireline scale economies long associated with infrastructural investment that led to regulated monopolies in the first place. From a public policy point of view, the spectrum pipe is the most important to protect, because, by definition, it can engage multiple players each with independently maintained infrastructure.

We can imagine, then, some general trends in competition for a spectrum-based broadband infrastructure to homes and businesses. First, the incumbents can be expected to resist and delay, clinging to traditional fixed service definitions, vague public service obligations and as long as possible, the traditionally high profit margins. Second, new players will enter, probably primarily from the computer and data transmission industries. They are likely to start by focusing on Internet service provision. But, in time, digital convergence will blur the distinctions between the Internet, telephony and television.

The computer industry has been living with Moore's Law for some time now. Computer scientists and PC consumers have come to expect that whatever is available today will be either twice as fast or half as expensive in about 18 months. The planning cycles and economics of the industry are derived from these steep learning and productivity curves.

The improvements in spectrum efficiencies and radio transmission cost reductions may not quite reach the canonic Moore parameter, but they are nonetheless dramatic. As the technologies press ahead, what can we expect on the regulatory front?

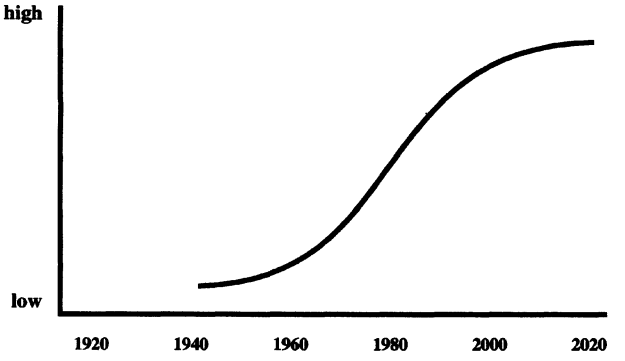

Figure 2,. Modulation Efficiency

Figures 2, 3 and 4 outline three elements of the digital revolution that will drive increasing pressure on spectrum innovation. Figure 2 depicts a theoretical curve for improvements in modulation efficiency. As digital technologies permit more information per unit bandwidth, each existing service can be redeployed in digital format, requiring less bandwidth for equivalent service and potentially freeing up bandwidth for other

applications. The key, of course, is the incentive for innovation that might be characterized as nearly nonexistent for spectrum incumbents.[28]

Figure 3 depicts the equivalent growth of interoperability. As the broadcast proponents of spectrum flexibility noted with unusual candor, although they started in the television business, with digital transmission

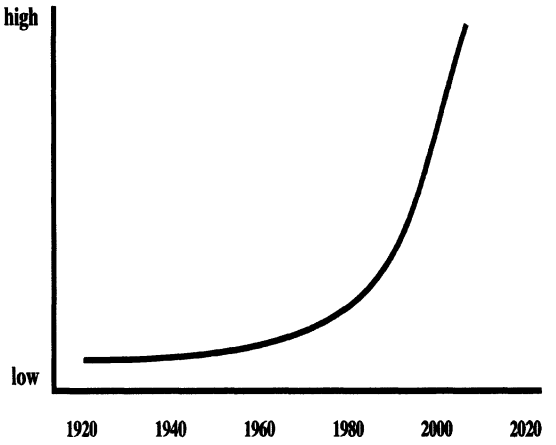

Figure 3. Interoperability

there is no technical limitation in providing other profitable services as well. As fashion and cost efficiencies push toward digitization, interoperability arrives, sometimes, it would appear, as an uninvited guest.

Figure 4 describes the critically important impact of cellular and geographic reuse technologies on broadband spectrum use. By traditional definitions, of course, broadcasting is one-way medium, telephone a switched two-way medium. Broadcasting is one-way because with analog transmission, it made sense to have one transmitter and many receivers. But as one moves the transmitters closer to the customer and lowers the power level the prohibition on duplex or two-way communication dissolves. The terrestrial spectrum becomes a promising candidate for two-way broadband communication.

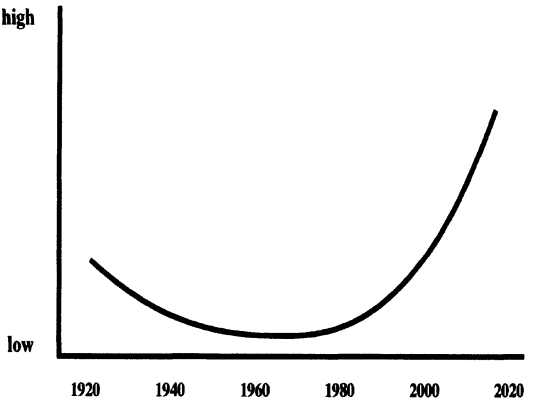

Figure 4. Duplex Communication Capacity

6. NET PRESENT POLITICS

Net present value is a common and widely accepted concept in business and financial planning. It permits the analyst to incorporate the time value of capital in evaluating projected cash flows. Perhaps a similar tool would be helpful in anticipating the future course of spectrum innovation. Let's call it Net Present Politics.

We might anticipate that there will be a cultural lag in industry sectors as broadcasters, cablecasters and telecommunications executives only gradually come to appreciate the impact of the Moore-style curves involving the economics and business practices of their industry sector.

Accordingly, we would expect the intensity of the spectrum wars to grow as incumbents and challengers take each other on in what were once relatively quiet corners of the spectrum allocation chart. As the conflicts heat up, the principles of interoperability and convergence become part of the business strategies of each industry and spectrum flexibility and open competition become commonplace. At this point, we might anticipate a decline in the traditional incumbent-challenger theatrics as the distinction between old uses and new uses of spectrum becomes less distinct.

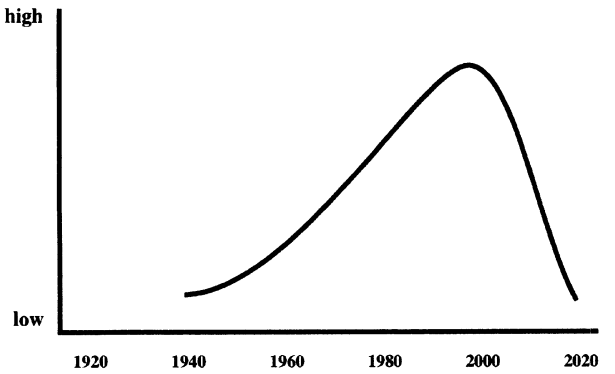

Figure 5. Time Line of Internal Resistance Spectrum Innovation

It might also take decades for the service-specific public interest standards of universal service and public trustee broadcasting to find redefinition that incorporates the principles of convergence. Perhaps at that point, the notion of Open Spectrum Access will appear to be self-evident and inevitable. But be prepared to wait a decade or two. There are a few battles left to be fought.

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[1] Paglin 1989

[2] Ostrom 1990

[3] Barron 1982; Rick Ducey of the NAB points out that a good-guys (government) and bad-guys (business) scenario is a misleading here as both public and private sector players are constrained by the political asymmetry of challengers and incumbents and that the battle is often waged among private sector combatants from different sectors, personal communication, 1998

[4] Calhoun 1988

[5] DeVany et al. 1969; Levin 1971, 1980; Fowler, Halprin and Schlicting 1986; Geller and Lampert 1989; National Telecommunications and Information Administration 1991; Hatfield 1992, 1993; Huang 1993; Noam 1995; Rosston and Steinberg 1997

[6] Barnouw 1966

[7] Lessing 1956; Barnouw 1966, Lewis 1991

[8] Barnouw 1966; Levin 1971

[9] Rohlfs, Jackson and Kelly , 1991; Calhoun 1988

[10] Comer 1998

[11] Register of Copyrights 1997

[12] Wilson 1980

[13] Krasnow, Longley and Terry 1982; Besen et al. 1984; Crandall and Furchtgott-Roth 1996

[14] Horwitz 1989

[15] Horwitz 1989

[16] Levin 1971; NTIA 1991; Joseph Gattuso of NTIA informs us that there are encouraging exceptions to this pattern in recent incumbent responses to NTIA requests for public comments on spectrum management, personal communication, 1998

[17] Pool 1983

[18] Levin 1971; NTIA 1991

[19] Coase 1959; De Vany et al. 1969; Levin 1971; Barron 1982

[20] Noam 1995

[21] Chuck Jackson notes that there is some controversy about feasibility. This isn't a near term prospect in any case, personal communication, 1998.

[22] Neuman, McKnight and Solomon, 1997; Brinkley 1997
[23] Paglin, 1989
[24] NTIA 1991, 90; see also Webbink 1977
[25] Neuman, McKnight and Solomon 1997
[26] Negroponte, 1995; MacKie-Mason, Shenker and Varian 1996; McKnight and Bailey 1997
[27] Neuman 1991; Neuman, McKnight and Solomon 1997
[28] Chuck Jackson points out this is less true for satellite, microwave and cellular incumbents