## Statement of Qualifications

## DR. LEE L. SELWYN

Dr. Lee L. Selwyn has been actively involved in the telecommunications field for more than twenty-five years, and is an internationally recognized authority on telecommunications regulation, economics and public policy. Dr. Selwyn founded the firm of Economics and Technology, Inc. in 1972, and has served as its President since that date. He received his Ph.D. degree from the Alfred P. Sloan School of Management at the Massachusetts Institute of Technology. He also holds a Master of Science degree in Industrial Management from MIT and a Bachelor of Arts degree with honors in Economics from Queens College of the City University of New York.

Dr. Selwyn has testified as an expert on rate design, service cost analysis, form of regulation, and other telecommunications policy issues in telecommunications regulatory proceedings before some forty state commissions, the Federal Communications Commission and the Canadian Radio-television and Telecommunications Commission, among others. He has appeared as a witness on behalf of commercial organizations, non-profit institutions, as well as local, state and federal government authorities responsible for telecommunications regulation and consumer advocacy.

He has served or is now serving as a consultant to numerous state utilities commissions including those in Arizona, Minnesota, Kansas, Kentucky, the District of Columbia, Connecticut, California, Delaware, Maine, Massachusetts, New Hampshire, Vermont, New Mexico, Wisconsin and Washington State, the Office of Telecommunications Policy (Executive Office of the President), the National Telecommunications and Information Administration, the Federal Communications Commission, the Canadian Radio-television and Telecommunications Commission, the United Kingdom Office of Telecommunications, and the Secretaria de Comunicaciones y Transportes of the Republic of Mexico. He has also served as an advisor on telecommunications regulatory matters to the International Communications Association and the Ad Hoc Telecommunications Users Committee, as well as to a number of major corporate telecommunications users, information services providers, paging and cellular carriers, and specialized access services carriers.

Dr. Selwyn has presented testimony as an invited witness before the U.S. House of Representatives Subcommittee on Telecommunications, Consumer Protection and Finance and before the U.S. Senate Judiciary Committee, on subjects dealing with restructuring and deregulation of portions of the telecommunications industry.

In 1970, he was awarded a Post-Doctoral Research Grant in Public Utility Economics under a program sponsored by the American Telephone and Telegraph Company, to conduct research on the economic effects of telephone rate structures upon the computer time sharing industry. This work was conducted at Harvard University's Program on Technology and Society, where he was appointed as a Research Associate. Dr. Selwyn was also a member of the faculty at the College of Business Administration at Boston University from 1968 until 1973, where he taught courses in economics, finance and management information systems.

Dr. Selwyn has published numerous papers and articles in professional and trade journals on the subject of telecommunications service regulation, cost methodology, rate design and pricing policy. These have included:

"Taxes, Corporate Financial Policy and Return to Investors"
*National Tax Journal*, Vol. XX, No 4, December 1967.

"Pricing Telephone Terminal Equipment Under Competition"
*Public Utilities Fortnightly*, December 8, 1977.

"Deregulation, Competition, and Regulatory Responsibility in the Telecommunications Industry"
*Presented at the 1979 Rate Symposium on Problems of Regulated Industries - Sponsored by: The American University, Foster Associates, Inc., Missouri Public Service Commission, University of Missouri-Columbia*, Kansas City, MO, February 11 - 14, 1979.

"Sifting Out the Economic Costs of Terminal Equipment Services"
*Telephone Engineer and Management*, October 15, 1979.

"Usage-Sensitive Pricing" (with G F Borton)
(a three part series)
*Telephony*, January 7, 28, February 11, 1980.

"Perspectives on Usage-Sensitive Pricing"
*Public Utilities Fortnightly*, May 7, 1981

"Diversification, Deregulation, and Increased Uncertainty in the Public Utility Industries"
*Comments Presented at the Thirteenth Annual Conference of the Institute of Public Utilities*, Williamsburg, VA - December 14 - 16, 1981.

"Local Telephone Pricing: Is There a Better Way?; The Costs of LMS Exceed its Benefits: a Report on Recent U.S. Experience."
*Proceedings of a conference held at Montreal, Quebec - Sponsored by Canadian Radio-Television and Telecommunications Commission and The Centre for the Study of Regulated Industries, McGill University*, May 2 - 4, 1984.

"Long-Run Regulation of AT&T: A Key Element of A Competitive Telecommunications Policy"
*Telematics*, August 1984.

"Is Equal Access an Adequate Justification for Removing Restrictions on BOC Diversification?"
*Presented at the Institute of Public Utilities Eighteenth Annual Conference*, Williamsburg, VA - December 8 - 10, 1986.

"Market Power and Competition Under an Equal Access Environment"
*Presented at the Sixteenth Annual Conference, "Impact of Deregulation and Market Forces on Public Utilities: The Future Role of Regulation" Institute of Public Utilities, Michigan State University*, Williamsburg, VA - December 3 - 5, 1987.

"Contestable Markets: Theory vs. Fact"
*Presented at the Conference on Current Issues in Telephone Regulations: Dominance and Cost Allocation in Interexchange Markets - Center for Legal and Regulatory Studies Department of Management Science and Information Systems - Graduate School of Business, University of Texas at Austin*, October 5, 1987.

"The Sources and Exercise of Market Power in the Market for Interexchange Telecommunications Services"
*Presented at the Nineteenth Annual Conference - "Alternatives to Traditional Regulation: Options for Reform" - Institute of Public Utilities, Michigan State University*, Williamsburg, VA. December, 1987.

"Assessing Market Power and Competition in The Telecommunications Industry: Toward an Empirical Foundation for Regulatory Reform"
*Federal Communications Law Journal*, Vol. 40 Num. 2, April 1988.

"A Perspective on Price Caps as a Substitute for Traditional Revenue Requirements Regulation"
*Presented at the Twentieth Annual Conference - "New Regulatory Concepts, Issues and Controversies" - Institute of Public Utilities, Michigan State University*, Williamsburg, VA. December, 1988.

"The Sustainability of Competition in Light of New Technologies" (with D. N. Townsend and P. D. Kravtin)
*Presented at the Twentieth Annual Conference - Institute of Public Utilities Michigan State University*, Williamsburg, VA, December, 1988.

"Adapting Telecom Regulation to Industry Change: Promoting Development Without Compromising Ratepayer Protection" (with S. C. Lundquist)
*IEEE Communications Magazine*, January, 1989.

"The Role of Cost Based Pricing of Telecommunications Services in the Age of Technology and Competition"

*Presented at National Regulatory Research Institute Conference*, Seatle, July 20, 1990.

"A Public Good/Private Good Framework for Identifying POTS Objectives for the Public Switched Network" (with Patricia D. Kravtin and Paul S. Keller) Columbus, Ohio: *National Regulatory Research Institute*, September 1991.

"Telecommunications Regulation and Infrastructure Development: Alternative Models for the Public/Private Partnership"
*Prepared for the Economic Symposium of the International Telecommunications Union Europe Telecom '92 Conference, Budapest, Hungary,* October 15, 1992.

"Efficient Infrastructure Development and the Local Telephone Company's Role in Competitive Industry Environment" *Presented at the Twenty-Fourth Annual Conference, Institute of Public Utilities, Graduate School of Business, Michigan State University, "Shifting Boundaries between Regulation and Competition in Telecommunications and Energy"*, Williamsburg, VA, December 1992.

"Measurement of Telecommunications Productivity: Methods, Applications and Limitations" (with Françoise M. Clottes)
*Presented at Organisation for Economic Cooperation and Development, Working Party on Telecommunication and Information Services Policies, '93 Conference "Defining Performance Indicators for Competitive Telecommunications Markets", Paris, France,* February 8-9, 1993.

"Market Failure in "Open" Telecommunications Networks: Defining the New "Natural Monopoly"
*Presented at the Tenth Michigan Conference on Public Utility Economics, Western Michigan University, Kalamazoo, Michigan,* March 26, 1993.

"Telecommunications Investment and Economic Development: Achieving efficiency and balance among competing public policy and stakeholder interests"
*Presented at the 105th Annual Convention and Regulatory Symposium, National Association of Regulatory Utility Commissioners, New York,* November 18, 1993.

"The Potential for Competition in the Market for Local Telephone Services" (with David N. Townsend and Paul S. Keller)
*Presented at the Organization for Economic Cooperation and Development Workshop on Telecommunication Infrastructure Competition*, December 6-7, 1993.

"Market Failure in Open Telecommunications Networks: Defining the new natural monopoly," *Utilities Policy*, Vol. 4, No. 1, January 1994.

*"The Enduring Local Bottleneck: Monopoly Power and the Local Exchange Carriers,"* (with Susan M. Gately, et al) a report prepared by ETI and Hatfield Associates, Inc. for AT&T, MCI and CompTel, February 1994.

*"Commercially Feasible Resale of Local Telecommunications Services: An Essential Step in the Transition to Effective Local Competition,"* (Susan M. Gately, et al) a report prepared by ETI for AT&T, July 1995.

"Efficient Public Investment in Telecommunications Infrastructure" *Land Economics*, Vol 71, No.3, August 1995.

"Market Failure in Open Telecommunications Networks: Defining the new natural monopoly," in *Networks, Infrastructure, and the New Task for Regulation*, by Werner Sichel and Donal L. Alexander, eds., University of Michigan Press, 1996.

*"The Cost of Universal Service: A Critical Assessment of the Benchmark Cost Model,"* (with Susan M. Baldwin) a report prepared for the National Cable Television Association, April 1996.

*"The BCM Debate: A Further Discussion,"* (with Susan M. Baldwin, et al) a report prepared for the National Cable Television Association, May 1996.

Dr. Selwyn has been an invited speaker at numerous seminars and conferences on telecommunications regulation and policy, including meetings and workshops sponsored by the National Telecommunications and Information Administration, the National Association of Regulatory Utility Commissioners, the U.S. General Services Administration, the Institute of Public Utilities at Michigan State University, the National Regulatory Research Institute at Ohio State University, the Harvard University Program on Information Resources Policy, the Columbia University Institute for Tele-Information, the International Communications Association, the Tele-Communications Association, the Western Conference of Public Service Commissioners, at the New England, Mid-America, Southern and Western regional PUC/PSC conferences, as well as at numerous conferences and workshops sponsored by individual regulatory agencies.

TESTIMONY OF

ROBERT STEARNS,

SENIOR VICE PRESIDENT, TECHNOLOGY AND

CORPORATE DEVELOPMENT,

COMPAQ COMPUTER CORPORATION,

BEFORE THE

SENATE COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION

ON THE

ELECTROMAGNETIC SPECTRUM MANAGEMENT POLICY REFORM AND

PRIVATIZATION ACT

JUNE 20, 1996

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JUNE 20, 1996

**Good morning, Mr. Chairman and members of the Committee.**

**I'm Bob Stearns, Compaq Computer Corporation's Senior Vice President for Technology and Corporate Development ... and its Chief Technologist as well.**

**In years past, I have testified before Congress and the FCC on a variety of communications issues of importance, and greatly appreciate the opportunity to testify today.**

**Compaq is the world's largest supplier of personal computers and the fifth largest computer company in the world, with 1995 world wide sales of $15 billion.**

**I might point out that's more than the combined sales of the three largest TV networks.**

**We've built Compaq's market position with an emphasis on open and voluntary technical standards and with a constellation of strategic partnerships, such as with Microsoft, that have permitted us to create products that meet real consumer needs.**

**With that as background, here are Compaq's views on the Electromagnetic Spectrum Management Policy Reform and Privatization Act.**

**To begin, Compaq agrees with Senator Pressler that spectrum is a valuable resource that should be made available on terms flexible enough to encourage its most innovative and efficient use.**

Outmoded, inefficient uses of spectrum -- such as analog NTSC[1] television broadcasting -- should be replaced as soon as feasible by uses that will better serve the marketplace and the public interest.

**Those to whom spectrum has been entrusted have an obligation to invest in the future ... even if that means doing business in a new and unfamiliar way.**

**I should mention that Compaq remains noncommittal about whether spectrum currently used or reserved for broadcast television should be auctioned.**

**But we do believe that the day when this spectrum can be returned to the government for re-use will be postponed <u>by years</u> ... if the FCC adopts the proposed Grand Alliance standard for digital television broadcasting.**

**Let's take a minute to focus on the Grand Alliance proposal.**

**Compaq believes this proposal is flawed.**

**<u>First</u>, it is <u>not</u> a standard at all but an amalgam of all the different formats that were being developed by the companies that joined forces to form the Grand Alliance.**

**<u>Second</u>, contrary to the way it's often portrayed ... it is <u>not</u> a "best of the best" proposal nor is it flexible.**

**Instead, it's really a grab bag of 18 different *mandated* formats.**

**And several of these formats incorporate outmoded, inefficient, and non-computer-friendly technology.**

**<u>Third</u>, if adopted by the FCC, the Grand Alliance proposal will straight jacket the future of digital broadcasting by effectively forcing digital TV receivers to decode <u>all 18</u> formats.**

**And that would <u>not</u> be in consumers' interests.**

**Why?**

**Because consumers would be forced to buy receivers capable of receiving all 18 formats ... including formats that may not deliver a discernible difference to their picture quality.**

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[1] National Television System Committee

What's more, think of the amount of processing power that will be needed to decode all of the formats.

Having to incorporate that processing power will significantly increase the cost of those television receivers and hybrid PC-TVs that are about to hit the market.

Consumers will be forced to spend billions of dollars--needlessly.

In fact, prohibitively high production costs may well keep digital TV receivers out of reach for average consumers and slow the rate at which digital broadcasting becomes viable.

At one time, the Grand Alliance technology may have been adequate for purely entertainment purposes.

But with the convergence of TVs and computers well under way, it is now obsolete.

And by the time -- many years from now -- that the average consumer is able to afford a set that can receive and decode all 18 formats ... the technology will have been surpassed by a whole new generation.

We all know that engineers are improving the capabilities of digital technologies relentlessly.

So why perpetuate obsolete technology for digital television when it's advancing so rapidly in all other industries?

It would be like forcing tomorrow's cars to use brake systems and suspensions from the 1980s.

Let's fast forward to the year 2000.

Under the trajectory set by the Grand Alliance, we see two undesirable consequences.

One, more than half of American viewers will continue to watch analog TV.

Two, valuable spectrum allocated for digital broadcasting will remain underutilized.

The year 2000 doesn't have to be this way.

Compaq sees an alternative ... a simpler, less-regulatory standard that would greatly reduce the cost of digital television receivers.

**We know Senator Pressler's bill envisions the government not mandating a standard for digital broadcast television.**

**From where we sit ... that approach is vastly preferable to the government's mandating a standard with *18* different formats.**

**That said ... let me underscore that Compaq and other members of the Computer Industry Coalition on Advanced Television Service ("CICATS") oppose the FCC's adoption of the Grand Alliance standard.**

**If the FCC decides that it should adopt *any* standard for digital television, we propose a minimal, but liberally enhanceable, baseline standard.**

**Our baseline standard would provide greater flexibility to broadcasters and equipment manufacturers.**

**It would significantly lower consumers' equipment costs.**

**It would accelerate the use of spectrum for digital broadcasting.**

**And more quickly free up spectrum for reuse that is now used for analog broadcasting.**

**For the past several months, Compaq and other computer and software companies have been advocating an improved digital TV standard that combines the best elements of the Grand Alliance's proposal.**

**The result is a flexible base layer format that would produce a huge qualitative improvement over today's analog TV ... yet at a cost that's a fraction of what's expected under the Grand Alliance proposal.**

**Best of all, the computer industry's proposal would provide interoperability between computers and digital broadcasting ... and accelerate the roll-out of affordable, interoperable products and services.**

You may be wondering why Compaq cares so much about a digital television standard.

The answer is that the convergence of PCs and TVs is making digital TV transmissions an important part of the National Information Infrastructure.

At least three major manufacturers -- Compaq among them -- have unveiled a new family of products that are best called "hybrid PC-TVs."

These devices will revolutionize the way Americans receive, store, and process interactive information, and provide limitless new opportunities for entertainment and education

This is not pie in the sky. It's ready to eat today.

PC-TVs are already on the market.

And in the near future, many of us will see our homes transformed into intelligent networked homes, with the PC as its nerve center.

For example, your living room PC-TV, with its advanced digital display, might offer a 60-inch screen and handle a variety of content that you've selected.

And a home local area network, modeled after the one at work, will enable a central home PC to drive displays in the study, the kitchen, the kids' rooms, and the family room

We envision your home having far more interactive and diverse communications links to the outside world--including voice and voice services, paging, videoconferencing, e-mail, online services, and Internet access.

And PC-TV hybrids will enable you to pull in digital content on demand, along with a wealth of information and services ... including sophisticated electronic commerce and banking ... telemedicine ... and distance learning.

If next-generation digital sets are less expensive and digital television is more computer friendly, this day will be here before you know it.

More consumers will be able to purchase digital receivers sooner, and digital TV will become a reality faster -- we believe 5 to 7 years faster under the computer industry single-format proposal.

Broadcasters will migrate to all-digital transmissions faster.

And spectrum can be returned for auction sooner.

If Congress wants to maximize the benefits and minimize the cost to consumers and taxpayers ... it should join us in discouraging the FCC from adopting the Grand Alliance's proposed digital TV standard.

Thank you very much for your time. I'm happy to answer any questions you may have.

Before the Federal Communications Commission
Washington DC 20554

In the Matter of
Advanced Television Systems
and Their Impact upon the
Existing Television Broadcast Service

MM Docket 87-268
Fourth Further Notice of Proposed Rule Making and Third Notice of Inquiry
9 August 1995

Informal Reply Comments of

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Research Laboratory of Electronics
Massachusetts Institute of Technology
Submitted 8 March 1996

*The opinions in these comments are those of the author only.*
*Since his retirement in 1990, the author has had no role in*
*directing MIT's Advanced Television Research Program.*

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## Executive Summary

These comments are directed at the Reply Comments of the Digital HDTV Grand Alliance, prepared by R. K. Graves Associates and submitted to the Commission on 22 January 1996. They are addressed specifically to the remarks about interlace and interoperability on pages 33-45. Those remarks include a number of technologically erroneous statements that are then used to support the contention that no harm can come from using an interlaced transmission format for ATV and that the interlaced format offers advantages to both the public and to the concerned manufacturers.

In this brief paper, it will be shown, by technical arguments only, that the use of interlaced transmission formats does not improve the vertical resolution for a given bandwidth and frame rate, does not require less bandwidth or channel capacity than progressive scan for the same resolution and frame rate, and is not necessary for permitting the manufacture of low-cost receivers. Thus there is no need to accept the artifacts and problems in transcoding caused by interlace or to give up the higher spectrum efficiency, the superior fine-detail rendition, and the better motion rendition provided by progressive scan.

*Based on these points, I propose that the transmission of interlaced formats be prohibited in both high-definition and standard-definition ATV broadcasting.* (Banning of interlaced receivers is not proposed.) I further propose, on the grounds of most efficient use of the over-the-air spectrum, that all ATV broadcasts (which would be in progressive format) utilize the full vertical definition that the number of scan lines makes possible. Since this would cause interline flicker on interlaced receivers, market forces will ensure that such receivers incorporate vertical low-pass filters to prevent flicker. If interlaced transmission is permitted, such filters should be required. At the very least, interlaced receivers without filters should be labelled to indicate that they will flicker with progressive transmission. Failure to adopt one or the other of these precautions will preclude any transition from interlaced to progressive scan transmission in the future. The interlaced format will then become the only format, and maximum efficiency in the use of spectrum will never be achieved.

1. Introduction

All commercial television systems to date have incorporated a system of interlace in which the odd lines of each TV frame are transmitted in one field and the even lines in the next. For example, the NTSC system, which sends 30 525-line frames every 1/30 second does so in two fields, each of 262.5 lines in 1/60 second. There are various ways to describe this process. One way is to think of it as doubling the large-area flicker rate. Another way is to say that the vertical resolution is doubled. Here we would be comparing a 30-fps 525-line interlaced picture with a 60-fps 262.5 line progressively scanned picture, both systems having the same bandwidth. The hope is that we can achieve the 525-line vertical resolution and the 60-fps flicker rate at the same time by using interlace.

Unfortunately, there is no free lunch. The interlaced picture shows more or less interline flicker, depending on the vertical resolution of the video information. The cause of this kind of flicker is the difference in brightness of vertically adjacent points that are in successive fields. In a picture devoid of detail, there is little interline flicker. (Even in blank areas, we may see some flicker when we look at the screen close up.) However, if there is a great deal of detail, flicker results, even as the screen is viewed from a distance. An extreme picture is one with alternate black and white lines, resulting in a black field followed by a white field. This would flicker at 30 cycles/second, and the flicker would be visible from across the room. Of course, ordinary pictures are not so full of detail -- they would flicker only in detailed areas.

All current camera tubes and solid-state camera chips automatically reduce the vertical resolution with the effect of getting rid of most of this flicker, so most TV engineers have never seen what would happen if full vertical resolution were present. Computer-generated video, particularly alphanumerics, does not have the same limitations as camera video, producing an unacceptable degree of flicker. As a result, computer displays have all used progressive scan for many years.

In all ATV systems, both SDTV and HDTV, the scanning formats of camera, transmission, and display are independent. This is different from today's TV, where all three formats are identical. Conversion between progressive (P) and interlaced (I) formats is possible. P to I is easier, since it only requires selecting every other line in every other field. I to P is somewhat more costly, since it requires generating a second set of scan lines, the best results requiring motion-compensated interpolation. If I receivers are used with P transmission, the conversion is cheap, especially since the ATV decoder requires the use of frame memories. I to P conversion would be required only at TV stations, where the converter cost would be negligible compared with the cost of the equipment required to enable any ATV transmission at all.

Because of the independence of camera, transmission, and display formats, each can be either P or I. The ATV system must be able to handle either P or I input material, since there is so much archival NTSC. Therefore, the encoder that produces the transmitted signal will surely be able to deal with either. Note that a progressive-scan signal with the same number of scan lines and frame rate as an interlaced signal (and therefore with twice the bandwidth) can be transmitted at the same data rate as the I signal after MPEG compression. (The reason for this is the greater redundancy and lesser aliasing of the P signal, as reported in a paper by Petajan of AT&T Bell

Laboratories.) *There is no data-rate penalty due to progressive transmission when coding is used.* Thus it makes a great deal of sense to use progressive transmission in all cases, and to permit both the signal source and the display to be either P or I. Of course, when all three are progressive, the highest quality is achieved.

*In summary, there is not a single compelling reason to use interlaced transmission formats in any new television system, and there are many reasons why this is a bad idea.*

Further details on these matters can be found in the Appendix.

2. Technologically Erroneous or Unsupported Statements in the Grand Alliance (GA) Reply Comments

2.1 The paragraph in the GA Reply Comments starting at the end of page 41 exemplifies the technologically faulty basis for the conclusions. Almost everything in this paragraph is incorrect.

> "For example, denied the use of an interlaced format for HDTV, viewers of a sporting event would have to watch the program with either of two inadequacies: (1) at a lower frame rate, resulting in objectionable motion judder during camera pans and fast action; or (2) at a lower spatial resolution, resulting in a loss of clarity and sharpness."

The writer seems to be comparing two uncoded analog formats, one progressive and the other interlaced, in which the former would have twice the bandwidth of the latter unless resolution or frame rate were reduced. Even for uncoded signals, I believe that quincunx scanning would give superior overall quality in the P format than in the I format, at equal bandwidth. However, in ATV, we are talking about coded digital systems, in which the data rate for the P and I formats are the same. In that case, the 720-line P format will have at least the same resolution as the 1080-line I format, as well as freedom from all interlace artifacts. It is not necessary to reduce either the frame rate or the spatial resolution in order to accommodate P scan, particularly in a coded system where progressive signals can be compressed to approximately twice the degree as interlaced signals.

> "In the case of SDTV, denying the use of interlaced formats would either incur one of these two penalties or would reduce the number of programs that could simultaneously be carried over the channel."

On the contrary, because of the higher compression ratio available to P signals, a larger number of programs can be simultaneously carried than if P signals are used for transmission. The 360-line P format, which, unfortunately, was rejected by the attendees at the ATSC T3/T6 conference of 14 March 1996, would do full justice to NTSC material. For high-end SDTV receivers using a 720-line P display, this would give quality substantially higher than that of NTSC and would permit more programs to be carried at the same time in a given channel.

> "Interlaced scanning enhances spatial resolution at a modest compromise in temporal frame rate."

Even in the uncoded analog form, interlaced scanning can enhance the spatial resolution only at the cost of unacceptable interline flicker, as previously explained. The compromise is not with frame rate, but with the interline flicker when it is attempted to get 525 lines vertical resolution with interlace in NTSC. This cannot be done with a conventional NTSC camera, which reduces vertical resolution by nearly 50% by averaging adjacent lines. In fact, the video information from a conventional NTSC camera is much like that from a camera that operates at 262.5 lines/frame, 60 fps, progressive scan.

> "While interlaced scanning may not be optimum for computer text and graphics applications, it has a long track record of proven value and successful use in traditional television broadcasting and has many staunch defenders."

This is the one statement in the paragraph that is correct. Interlace is not optimum for text and graphics. (Note that computer-generated graphics are widely used in NTSC at present, causing interline flicker unless "antialiased," i.e., low-pass filtered.) NTSC with its I format has been a commercial success for more than 4 decades. One has to ask the question as to why we want to change it now. (See below.) If it is to be changed, then we certainly ought to replace it with a system that is as efficient in its use of spectrum as possible. As for the "staunch defenders," most of them were pushing for an NTSC-compatible HDTV system a few years ago and virtually none foresaw digital transmission.

> "In addition broadcasters must be concerned with the interoperability of an ATV transmission standard with currently available HDTV production equipment and with the installed base of NTSC production and studio equipment, virtually all of which employ interlaced scanning."

In promulgating broadcasting standards for the United States, the Commission need not cater to the obvious desire of enthusiasts for the NHK system to facilitate the use of existing 1125-line equipment in ATV, either HDTV or SDTV. The MUSE transmission version of the 1125-line NHK system was tested at ATTC and found inferior to the systems now incorporated in the Grand Alliance format. If ATV broadcasting takes hold in the US, we can be sure that foreign companies will be quick to offer appropriate equipment. As for compatibility of the progressive ATV transmission standard with existing NTSC studio equipment, an I-to-P converter is required, the cost of which will be entirely negligible compared to the other costs of switching to digital transmission.

2.2 The second paragraph on page 42 relates to support in the industry for a standard with more than 1000 lines.

> "There is a substantial body of broadcasters and others who believe that a high-definition format must have more than 1000 lines to be successful."

While it is true that there is such a body of believers, their belief is incorrect. They are speaking about the number of lines in the picture rather than the actual vertical definition of the displayed image. Their mistaken belief is that the definition is proportional to the number of scan lines

without regard for whether interlace is used or not. The resolution of the NHK 1125-line interlaced system, as shown on test patterns, was barely above 700 lines. The resolution of the GA 1080-line interlaced format will be less. On the other hand, the resolution of the 720-line progressive format from a good camera will be 720 lines. If one wanted super quality on high-end HDTV receivers, the 720-line signals could be presented on a 1440-line display.

An argument often made by the interlace proponents is that the 720-line progressive format does not have high enough vertical resolution. *However, the proposed 1080-line interlaced format will not have higher resolution; it may well have lower resolution.* Even with a perfect as-yet-not-invented camera, the interlaced format cannot have anywhere near 1000 lines vertical resolution without producing totally unacceptable flicker on the interlaced display.

That the interlace proponents do not understand this point is also shown by the change, after the first round of laboratory tests, from 960 lines (as used in the original ATRC system) to 1080 lines just to get over the magic number of 1000. (Remarkably, this change also makes the 1125-line equipment suitable for production in the GA system.) It is not clear exactly what resolution is needed to make HDTV a success, or even whether it is the vertical resolution that holds the key to success. In any event, the use of interlace has nothing to do with it; *interlace cannot raise the vertical resolution.*

> "...the proposed U.S.ATV standard...stresses progressive scan and square pixels."

It is true that most of the formats in the GA system are progressive. That does not amount to stressing progressive scan, since the presence of any interlaced format is likely to result in the death of all the P formats. The reason is that the first receivers will be interlaced, both to reduce costs and because that is what the manufacturers mistakenly prefer. (See below.) Full-definition P signals would cause unacceptable interline flicker on these first receivers, creating an intractable incompatibility problem. In that case, without the mandatory use of vertical low-pass filters (a step to which the GA Reply Comments strongly object) it is highly likely that progressive transmission will never be used.

2.3 The first full paragraph on page 43 includes the following:

> "...insistence on banning interlaced formats is unwarranted and self-serving."

In the foregoing, I have given ample technological justification to warrant the banning of interlaced transmission formats. The "self-serving" issue is nontechnological and is discussed below in Section 3.

2.4 The paragraph beginning at the bottom of page 43 discusses the desire of computer interests to use more than 60 frames/sec. This is now common in computer displays, as it considerably reduces eyestrain caused by extended close-up viewing of high-resolution graphics.

> "...increasing the transmission frame rate higher than 60 Hz would have to come at the expense of either reduced spatial resolution or increased compression artifacts..."

This is pure speculation. It may well be that a higher frame rate would reduce aliasing and increase redundancy to a degree that would permit the maintenance of spatial resolution without substantially worsening artifacts. The fact that P signals, with twice the analog bandwidth, can be coded to about the same data rate as I signals is quite suggestive. Under present conditions, it is unlikely that this point will be properly investigated. It is true, however, that good-quality conversion from 60 to 72 fps requires motion-compensated interpolation, which is not very simple.

2.5 The paragraph beginning on page 44 contains a number of nontechnically supported statements about interoperability that are discussed below.

3. Nontechnological Issues

A number of statements in the GA Reply Comments that are used to support the conclusions cannot be discussed on a purely technological basis. Even if no completely objective assessment of these points is possible, they are nevertheless important. What follows, therefore, represents my opinions based on my knowledge and study of the TV industry rather than conclusions that I have reached strictly on the basis of science in Section 2.

3.1 The second paragraph on page 33 expresses the belief that all the receivers to be manufactured will be able to cope with all the formats in the GA system, even without any mandate by the Commission.

One has to wonder why so many formats are included in the proposed standard. Without the slightest doubt, this will increase the cost of all ATV receivers, including the cheapest ones. It is no secret that the "Alliance" was imposed on the several proponents. I speculate that none of these reluctant partners was willing to give up his own format, so all were included. Of course, the GA cannot ensure that all manufacturers, even those in the Alliance, will follow this dictum. A manufacturer who is interested in keeping the sales price as low as possible and the profits as high as possible is highly likely to omit some formats. The first one to fall by the wayside, in my opinion, will be the 24-fps film format (actually an excellent format), followed by the 720-line P format, particularly if little or no broadcasting is done with either, as seems likely.

3.2 The last paragraph on page 36 objects to the required labelling of NTSC-only receivers to the (accurate) effect that such receivers will not be able to deal with digital broadcasts once the definite turn-off date for NTSC has been set. The protection of consumers by such labelling is widely accepted, from warnings about the suffocation danger of plastic bags and about the health hazards of cigarettes to listing the nutritional ingredients on most packaged food. As a citizen, I find it hard to justify withholding such vital information from consumers. Experience demonstrates that industry cannot be relied upon to inform the public in such cases, since the manufacturers who voluntarily do so are placed at an immediate disadvantage in the market as compared with those who do not. *Labelling requirements of this type are a protection, not only for consumers, but for the majority of manufacturers who want to do the right thing.*

3.3 The Motivation to Shift from NTSC to ATV

For all its defects, NTSC has been a very effective system. We are approaching 200 million receivers in the US, and TV has become the primary form of entertainment and information transmission. Many organizations have made and are continuing to make significant profits, and the public spends a great deal of time in front of the tube.

The original motivation to shift to ATV, as determined by the Commission, was to get the benefit of vastly improved picture and sound quality. Now that it appears that multiple standard-definition signals can be transmitted in each 6-MHz channel and that some of the NTSC taboo channels can be used, the main motivation is spectrum efficiency. This term relates to the amount of TV service, as measured by the number of program choices of a given technical quality available to each viewer, for a given amount of spectrum allocated to the service. Note that the number of programs that can be accommodated is inversely proportional to the required data rate of each.

Regardless of the degree to which the public cares about image quality, (everyone knows that the public cares mostly about program content) the Commission is making a trade-off between technical quality and amount of service when it sets a standard. *It therefore behooves the Commission to set a standard that gives the maximum technical image and sound quality for a given data rate.* In this respect, progressive scan is superior and should be selected. Interlaced transmission should not be permitted because it is likely to drive out progressive scan just as bad money drives out good money under Gresham's Law.

3.4 The "Self-Serving" Issue

It is puzzling why the GA Reply Comments raise this issue in the first paragraph on page 43 (even quoting Scripture!), since it is sure to generate skepticism among the readers. (Let the pot not call the kettle black, as folklore wisely suggests.) It should be recognized that nearly all the parties to the FCC proceedings are commercial establishments in the business of making money. The actual inventors all have their pride at stake, whether they hope to make money or not. In such circumstances, all parties can be expected to advocate Commission action that is in their own perceived interest. Under our form of government and our economic system, this is perfectly proper. It is for the Commission to make its decisions in the public interest. Parties to the proceedings are well advised to base their proposals as much as possible on verifiable facts.

Further on in this paragraph, the GA states that the market will choose progressive scan if it proves to be superior. The market will not have that choice. As I have pointed out in Section 2, above, the use of interlaced transmission, which surely would encourage the marketing of interlaced receivers, means that the full vertical resolution of progressive formats could never be used because it would cause unacceptable flicker on interlaced receivers that did not incorporate vertical low-pass filters. This means that the full spectrum efficiency of a new system could never be realized.

Finally, the GA upbraids the computer industry because of the incompatibility of the Mac and the

PC. This complaint comes with particularly poor grace from an industry that produced the Beta-VHS debacle that cost manufacturers, users, and the video-rental business a substantial monetary loss and inconvenience.

A more valid complaint that might have been made against the computer industry, which is larger and much more profitable than consumer electronics, is that it was unwilling to spend the money required to develop an ATV system that would meet its own interests as well as those of the consumer-electronics industry and the public. The Grand Alliance members did spend the money. It is my opinion, which I have voiced many times, that a much better system could have been developed if the computer industry had been willing to put its money where its mouth was. Regardless of these considerations, the decisions that the Commission must take at this time ought to be in the public interest, independent of the alleged moral superiority of any of the interested parties.

## 4. Conclusions

In this paper, I have tried to show, on technical grounds only, that interlaced transmission should not be permitted for either HDTV or SDTV. In addition, progressive transmissions should be required to be at full vertical resolution. If this were done, it would not be necessary to ban interlaced receivers.

The fundamental reason for my proposal is that interlaced transmission would make any subsequent transition to progressive transmission pointless. The higher vertical resolution and spectrum efficiency inherently available with progressive transmission could not be used since it would cause unacceptable interline flicker on the interlaced receivers that would certainly be sold for use with interlaced transmission. It is conceivable that interlaced receivers would not cause this trouble if vertical low-pass filters were mandated in such receivers, but it is unlikely that either the manufacturers or the Commission would accept such a requirement. ATV transmission in progressive format only with full vertical resolution would result in interlaced receivers being so equipped without any mandate from the Commission.

## 5. Appendix

The appendix comprises four short notes written between 1993 and the present. The first, "Excellent Television Engineers and Interlace" demonstrates that many highly experienced TV engineers have never seen the kind of interline flicker that occurs when the vertical definition of the video information is very high. The second, "A Few More Words About Interlace" is a recent piece in which I tried to debunk, in very simple terms, the most prevalent misconceptions about interlace. It was prepared for the ATSC T3/T6 meeting of 3/14/95. The third, "Some More Thoughts About Interlace," which I prepared after the NIST meeting at Georgetown University 10-11 May 1995, recounts some of the happenings at the meeting and also attempts to educate engineers on this subject. In addition, it recounts our experience at MIT showing a side-by-side demonstration of interlace vs progressive scan, in which *none* of the hundreds of experienced engineers who saw the demo had ever seen anything like it. The fourth, "Interlace," written in 1993, gives a brief but somewhat deeper account of the technical issues, in the simplest possible terms.

# Excellent Television Engineers and Interlace

A lot of excellent TV engineers work for Sony. During the project at MIT that was sponsored by Sony some years ago, we had a 512-line interlaced display connected to the frame store on our TV system. We usually got our pictures from a high-res laser scanner in which the adjcent scan lines were entirely independent. The interline flicker was spectacular – like what one sees on a VT-100 in the interlaced mode with computer-generated alphanumerics. It could be seen from across the room.

** Note: One does not have to resolve the scan lines to see the interline flicker. What is flickering is the object that differs on adjcent scan lines; said object can be quite large. For example, if the odd lines are black and the even lines are white (a legitimate TV picture, though rare) it flickers at 30 Hz and one can see the flicker at any distance. In practice, with high vertical resoultion at the source, iterlaced displays flicker in all busy image areas, and this flicker can be seen even when one does not visually resolve the scan lines. It's only in blank areas that they don't flicker.**

What was most interesting was the reaction of the Sony people. They wanted to know what was wrong with the monitor!

This reaction was so striking that, when we had the right equipment, we set up a side-by-side demo of an interlaced and progressive monitor with the same still picture. It was the back of a dollar bill, with four different kinds of vertical filtering. (There are some filters that somewhat reduce the flicker without as much loss of vertical resoultion as normal.) We showed this to hundreds of visitors. No one had ever seen this phenomenon before, and this includes executives and working guys from ABC, NBC, CBS, Harris, Tektronix, PBS, Ampex, Kodak, Zenith, and all our other sponsors.

The basic reason for this is that in normal NTSC (and PAL and SECAM), the cameras erase the entire screen every field, and thus have a true vertical resolution only about half what one would think. It is this reduced resolution that avoids the flicker. If the screen doesn't flicker, then progressive scan doesn't help.

People normally think of interlace as a way to double the large-area flicker rate with a given bandwidth. Another way is to use it to double the vertical resoultion as compared with a progressive system with half the lines. This is discussed in E.F. Brown, BSTJ 46, 1, 199-232, 1967. He found that the improvement depended on luminance and was only about 10% at normal CRT luma. INTERLACE DOESN'T WORK; WE ONLY THINK IT DOES.

# A Few More Words About Interlace

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Although there are many other important considerations in choosing formats for "standard" definition digital TV transmission, in this short note, I shall deal only with interlace. There is no more troubling issue in TV standards-setting, and apparently none in which entrenched positions are more difficult to move. Some have dismissed the entire controversy as religious in nature, but I think this misses the point. In TV issues, it is possible for most of those involved to be wrong at the same time. We have only to look at what has happened in the period of the FCC Inquiry since 1987. Most participants were wrong on the simulcast-vs-compatible-system issue, the digital-vs-analog issue, and on the question of whether HDTV could be transmitted in the 6-MHz analog channel. Many of these very same people are among those most adamant that interlace must be a part of any new TV standard. Here are some of the points that have been raised together with a brief discussion of each.

**Interlace doubles the vertical resolution for a given bandwidth and frame rate.**
This is the most important technical issue. In fact, with interlace (I), the hoped-for factor of two improvement in vertical resolution must be reduced by nearly 50% (depending on screen brightness) to avoid totally unacceptable interline flicker. A study by Bell Laboratories in 1967 showed that, at normal brightness, only a 10% increase in vertical resolution could be obtained with acceptable interline flicker. Against this marginal improvement, we must balance the many other artifacts caused by interlace, including the disappearance of half the scan lines with vertical motion of an integral number of lines per frame. Progressive scan (P) has none of these artifacts.

**P scan requires more bandwidth or channel capacity than I for the same resolution.**
This is the next most important technical issue and one that we have fought over for a long time. Even at the uncoded analog video-signal level, right out of the camera, the same bandwidth, and therefore the same SNR, can be had by using "quincunx" sampling, which involves sampling alternate points on alternate lines. The progressive scan pictures thus sampled would have lower diagonal and higher vertical resolution, and they would be completely free of the artifacts long associated with interlace. At the digitally coded transmission level, Petajan at AT&T Bell Labs has demonstrated that the coded P signal, with full diagonal resolution and *twice* the analog bandwidth, requires the *same* digital data rate as the coded I signal. Of course, it is also free of all of the I artifacts.

**We have to have interlace so that we can have cheaper receivers.**
If transmission is progressive scan, receivers can still be interlaced, and therefore slightly cheaper. It is very easy to convert from P to I by omitting every other line in every other field. In the case in which (as I believe should be mandated), the P transmission has full vertical resolution, a vertical filter is required to prevent interline flicker on the I receiver. The cost should be no more than that of a comb filter. The filter could be switched in under control of a header in the transmission. *If no such filters are required in interlaced SDTV receivers, then P transmission with full vertical resolution will not be possible because it will cause flicker on these receivers.*