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An Estimate of the Potential Costs of Guidelines Limiting Public Exposure to Radiofrequency Radiation from Broadcast Sources

Volume 1: Report

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AN ESTIMATE OF THE POTENTIAL COSTS OF GUIDELINES LIMITING PUBLIC EXPOSURE TO RADIOFREQUENCY RADIATION FROM BROADCAST SOURCES

Volume 1: Report

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PREFACE

The purpose of the study reported here is to estimate the potential cost of a federal guidance proposed by the Environmental Protection Agency (EPA) limiting public exposure to radiofrequency (RF) radiation. An estimate of the economic effects of proposed federal actions is mandated by a series of Executive Orders (EOs), the latest of which is EO 12291, Federal Regulation, which is implemented by an Office of Management and Budget guidance on regulatory impact analysis and, in EPA, by a companion guideline for performing regulatory impact analyses. The federal radiofrequency radiation protection guidance has been developed by the EPA under the Federal Radiation Council Authority, 42 U.S.C. 2021(h), transferred to EPA by EO 10831, Reorganization Plan Number 3 of 1970 and by Public Law 86-373.

The EPA has conducted research over the past 12 years on the electromagnetic environment to which the public is exposed and on the propagation of RF by a wide variety of sources, the most significant of which are AM and FM radio, VHF-TV and UHF-TV broadcast stations. The cost study is limited to these significant sources of RF. One of the results of this study, in conjunction with EPA research, is a conceptual development of the type of mitigation measures necessary to effect compliance, as indicated by model results at 18 alternative guidance levels ranging from 1 $\mu W/cm^2$ (FM and TV) or 10 V/m (AM) to 10,000 $\mu W/cm^2$ (FM and TV) or 1,000 V/m (AM). The cost of compliance was estimated using a series of models that present a range (low, medium, and high) of costs to society-at-large, costs to the broadcast industry and costs to and effects on the net income of the average broadcast station. The costs are expressed in a variety of ways, including gross cost, net annual cash flow cost, average annual cash flow cost, and present value.

The report is organized into two volumes, the first a description of the study and a summary of results, the second a series of appendices containing an explanation and sample of the calculations for each of the three segments of the broadcast industry; the appendices also include detailed tabular and graphic descriptions of various cost estimates at each of the 18 guidance levels at the three cost levels. Volume I begins with a preface, executive summary, and abstract, followed by an introduction in which a discussion of the purpose and scope of the study lead to an extensive graphic presentation of conclusions supported by summary tables. Following this is a background section outlining the purpose for and current efforts to regulate RF radiation, public and industry concerns over RF and its regulation, a brief review of the electromagnetic environment and of health effects research, a profile of commercial broadcast facilities and a discussion of the framework for regulatory (economic) impact analyses.

The next section describes the method of approach used in the cost study. Following this is a section describing the compliance measure concepts developed by the EPA and consultants as part of this study. The remaining section describes the cost models--social, industry, and average firm. All assumptions, including costs, application of compliance measures and financial parameters, are discussed throughout and summarized at the conclusion of Volume I for convenience.

Volume II contains three appendices, one each for AM and FM radio and TV broadcast stations, that present a step-by-step explanation of each of the calculations in the cost models. Those are followed by other appendices that present detailed estimates of the cost of compliance with 18 guidance levels at three cost levels, given in terms of the cost to society-at-large, the cost to industry, and the cost to the average broadcast firm; in addition, the number of stations requiring a compliance measure at each guidance level is given. The average annual cash flow cost and present value estimates are plotted for each of the three analyses (social, industry, and average firm) at three cost levels. These are supported by data in the tables, which also contain other cost analyses not plotted.

This two-volume report is one of a number of documents presenting research that was used to develop the proposed RF guidance and provide analyses for reviewers and decision makers considering it. A presentation of the engineering and health studies is contained in three reports published or in preparation by the U.S. Environmental Protection Agency. A review of over 5000 citations of health risks and biological effects of RF is given in U.S. Environmental Protection Agency, Biological Effects of Radiofrequency Radiation, J. A. Elder and D. F. Cahill Eds., Health Effects Research Laboratory, Research Triangle Park, North Carolina, EPA-600/8-83-026F, September 1984. A study of the engineering aspects of radiofrequency radiation is contained in Gailey, P. C. and R. A. Tell, An Engineering Assessment of the Potential Impact of Federal Radiation Protection Guidance on the AM, FM, and TV Broadcast Services, U.S. Environmental Protection Agency, Washington, D.C. (in press). A third report has been prepared on the radiofrequency environment: Hankin, N. N., The Radiofrequency Radiation Environment; Environmental Exposure Levels and RF-Emitting Sources, U.S. Environmental Protection Agency, Washington, D.C. (in press).

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EXECUTIVE SUMMARY

The purpose of this study is to estimate the potential cost of a federal guidance limiting public exposure to radiofrequency (RF) radiation; the study addresses the cost of compliance of the broadcast industry and its three major segments--the 9000 AM and FM radio stations and the 1000 VHF-TV and UHF-TV broadcast stations in the U.S. The cost of compliance was estimated in terms of three kinds of economic analyses, for which models were developed: the cost to society-at-large, the cost to the broadcast industry, and the cost to and effect on the net profit of the average broadcast station. For these analyses, estimates were made of the cost of 18 alternative guidance levels ranging from 1 $\mu W/cm^2$ (FM and TV) or 10 V/m (AM), the most stringent, to 10,000 $\mu W/cm^2$ (FM and TV) or 1000 V/m (AM), the least stringent, using a low, medium, and high estimate of the cost of components for compliance measures.

The federal RF radiation protection guidance analyzed in this study has been developed and proposed by the U.S. Environmental Protection Agency (EPA) under the authority of the Federal Radiation Council, 42 U.S.C. 2021 (h), which was transferred to the EPA by Executive Order (EO) 10831, Reorganization Plan Number 3 of 1970 and by Public Law 86-373. Accordingly, the Nonionizing Radiation Branch, Office of Radiation Programs of the EPA has conducted an extensive research program over the past 12 years on the electromagnetic environment to which the public is exposed. This research has included a number of studies of the propagation of RF by a wide variety of sources including shortwave (high frequency) radio, satellite communication earth terminals, point-to-point microwave radio antennas, various kinds of radar, land/mobile communications, and hand-held transceivers. This research indicates that the broadcast industry, FM radio and VHF-TV transmitters in particular, contribute the majority of RF to which the public is exposed in the general environment. Therefore, the EPA has focused on the broadcast industry as the most important foundation for a cost study and has developed models that estimate the RF energy deposition on the ground from AM and FM radio, VHF-TV and UHF-TV antennas. The models use a data base the EPA developed by combining information manually extracted from Federal Communications Commission engineering files with results of studies of the propagation characteristics of various commonly used antennas. Using these models the EPA has estimated the RF pattern and intensity of all 10,000 AM and FM radio, VHF-TV and UHF-TV broadcast stations. These RF propagation estimates were compared with the 18 specified guidance levels; for those stations estimated to exceed a given guidance level, a series of increasingly complex, effective, and costly compliance measures was tried in succession until compliance was indicated by model results. This provided the engineering basis for the cost models.

An estimate of the economic effects of proposed federal actions is mandated by a series of Executive Orders, the latest of which is EO 12291, Federal Regulation, which is implemented by an Office of Management and Budget guidance on regulatory impact analysis and, in EPA, by a companion guideline for performing regulatory impact analyses. Accordingly, the EPA contracted with the Environmental Sciences Division of the Lawrence Livermore National Laboratory under EPA-DOE (Department of Energy) Interagency Agreement AD-89-F-2-803-0 to conduct the cost study.

The social cost models estimate the entire cost to society-at-large, defined as the opportunity cost of allocating resources for the purpose of reducing RF radiation at the exclusion of other uses, in terms of component and gross cost, annual cash flow (undiscounted) cost and present (discounted) value of the cost of the guidance. The industry cost models estimate the annual and average cash flow (undiscounted) cost and present (discounted) value of the cost of compliance. The average firm models estimate the annual gross cash flow (undiscounted) cost, tax shelter, net annual and average cash flow cost, net income after compliance and present value of the cost of compliance. The industry and average firm models produce results that are net of income tax deductions and credits and include the cost of financing the required compliance measures.

The results show that the cost of compliance in all three analyses drops very rapidly from guidance level 1 to 4, then rapidly from 4 to about 9 or 10, and then more gradually to level 18. The percentages of stations requiring a mitigation measure are 94% (FM), 100% (AM), and 76% (TV) at guidance level 1; at guidance level 18 the percentages requiring a mitigation measure are 1% (FM), 0% (AM), and 0% (TV). The present (discounted) value of the cost to society-at-large of compliance with the proposed RF guidance varies from a maximum (high cost assumptions) of $866.6 million for guidance level 1 to a minimum (low cost assumptions) of $12.7 million for guidance level 18. The annual cash flow (undiscounted) cost to society varies from $207.8 million to $3.1 million. The present value of the net after tax cost to the broadcast industry varies from $414.6 million to $6.9 million. The average annual net after tax cash flow cost to the broadcast industry varies from $59.1 million to $0.8 million. The average present value of the net after tax cost to the average broadcast firm varies from a maximum of

$40.6 thousand (FM), $7.9 thousand (AM), $285.3 thousand (TV) to a minimum of $4.8 thousand (FM), $1.3 thousand (AM), $0.7 thousand (TV). The average annual net after tax cash flow cost to the average broadcast firm varies from a maximum of $9.7 thousand (FM), $1.8 thousand (AM), $67.8 thousand (TV) to a minimum of $1.1 thousand (FM), $0.3 thousand (AM), $0.1 thousand (TV). The reduction in the net profit of the average broadcast firm from maximum cash flow expenses associated with compliance varies from a maximum of 16.4% (FM), 5.1% (AM), 8.4% (TV) to a minimum of 2.5% (FM), 1.4% (AM), 0.1% (TV). The reduction in the net profit from the average cash flow expense of compliance is about 50% of the maximum percent effect on profits.

ABSTRACT

The purpose of this study is to estimate the cost of a federal guidance proposed by the U.S. Environmental Protection Agency (EPA) limiting public exposure to radiofrequency (RF) radiation from the broadcast industry--the 9000 AM and FM radio stations and 1000 VHF-TV and UHF-TV broadcast stations in the U.S.-- that EPA research indicates is the most significant source of RF to which the public is exposed. The Lawrence Livermore National Laboratory developed models that estimate a variety of costs at 18 alternative guidance levels for three kinds of economic analysis: the cost to society-at-large, the cost to the broadcast industry and the cost to and effect on net profit of the average broadcast station. The total present (discounted) value of the cost to society varies from a maximum (high-cost assumption) of $866.6 million for guidance level 1 and drops very rapidly to guidance level 4 then rapidly to level 10 and more gradually to a minimum (low-cost assumption) of $12.7 million for guidance level 18. The maximum reduction in net profit from increased cash flow costs to the average broadcast firm over the assumed 6 years of costs varies from 16.4% (FM) at guidance level 1 to 0.1% (TV) at guidance level 18.

INTRODUCTION AND BACKGROUND

PURPOSE

The goal of this study is to assist the Environmental Protection Agency (EPA) in addressing the cost of regulation as mandated by Executive Order (EO) 12291[1], by Office of Management and Budget (OMB) guidance on regulatory impact analysis[2], and by EPA guidance on regulatory impact analysis.[3] To accomplish this goal, Lawrence Livermore National Laboratory (LLNL) has developed and applied a methodology to analyze the potential cost of a Federal guidance limiting public exposure to radio freqency (RF) radiation proposed by the EPA. At the time this analysis was conducted, important categories of benefits had been identified but not quantified.

The purpose of this study, to develop and apply a cost methodology, was carried out by developing models that estimate a variety of costs of compliance for three types of economic analysis: the cost to society-at-large, the cost to the broadcast industry, and the cost to and effect on the net profit of the average broadcast firm. Using the results of an engineering analysis provided by EPA,[4] we made estimates of the cost of 18 alternative guidance levels ranging from 1 μW/cm^2 (FM and TV) or 10 V/m (AM), the most stringent, to 10,000 μW/cm^2 (FM and TV) or 1,000 V/m (AM), the least stringent, using three levels of costs for compliance measure components. Among the costs estimated for each of the three analyses are component and gross compliance cost, projected actual and average annual cash flow (undiscounted) cost, and present (discounted) value. The average firm models estimate the net after tax effect of compliance on profit.

SCOPE

Anthropogenic sources of RF are many and are proliferating. Contributors to the general RF environment include point-to-point and earth-satellite communication system microwave broadcast antennas, military and civilian defense and navigation radar, land-mobile transmitters, hand-held transceivers, police traffic control radar, medical diathermy, commercial and residential microwave ovens, industrial sealers and heaters, shortwave radio, commercial FM and AM radio, VHF-TV and UHF-TV broadcast sources. Continued development of applications of RF energy in industrial processes and the communications industry such as the emerging low-power TV stations, cellular radio, and high-density TV, will increase the number of sources of RF. This study focuses on the existing commercial technology of the broadcast industry, because EPA's Office of Radiation Programs (ORP) research over the past 12 years indicates that this industry and FM and VHF-TV transmitters in particular are the most significant sources of RF to which the public is exposed.

RESEARCH RESULTS OVERVIEW

The EPA originally established 18 VHF field intensity levels as the basis of the economic study. The majority of the cost estimates were performed with the assumption that the frequency dependency of the guidance levels would be structured with the FM and TV limit (in $\mu W/cm^2$) established uniformly about 26.5 times more stringent than the AM limit for all 18 guidance levels studied. However, the EPA is now considering three alternative frequency-dependent guidance options: for option 1, the FM and TV limit (in μWcm^2) is 20 times more stringent than for AM; for options 2 and 3, the FM and TV limit is 200 times more strigent than for AM. The three alternative regulatory options thus have a different relationship between the limits applied to the AM band and those applied to FM and VHF-TV frequencies from the guidance levels used originally in the cost analysis. However, because each of the three broadcast services was analyzed independently at 18 different guidance levels, the total cost of any frequency-dependent standard can be estimated by combining the cost to each service at the guidance level applied to that service. The alternative guidance options currently under consideration for proposal by the EPA are structured for the three broadcast services as follows:

EPA Alternative Guidance Options

	Limiting field strength at AM frequencies V/m			Limiting power densities at FM and TV frequencies μW/cm²		
	New guide option field strength	Nearest lower cost study field strength	Cost study guide level	New guide option field strength	Nearest lower cost study field strength	Cost study guide level
Option 1	87	86.6	5	100	100	6
Option 2	275	264.6	12	200	200	7
Option 3	614	446.7	16	1000	1000	15

Using the nearest lower, more expensive, guidance level when the new option falls between two guidance levels used in the cost study,[a] we estimated the social, industry, and average firm costs of compliance with the three new options. Figures 1-3 indicate the present value of the cost to society, industry and the average firm, respectively. The total present value of the cost to society varies from a maximum of $93.4 million (high-cost assumptions) for option 1 to $15.9 million (low-cost assumptions) for option 3 (Fig. 1). The total present value of the cost of compliance to the broadcast industry varies from a maximum of $45.6 million (high cost) for option 1 to $8.4 million (low cost) for option 3 (Fig. 2). The average present value of the cost of compliance for the average firm varies from a maximum of $22.0 thousand (FM), $2.6 thousand (AM), $70.3 thousand (TV) for option 1 (high cost) to a minimum of $6.4 thousand (FM), $1.3 thousand (AM), $23.1 thousand (TV) for option 3 (low cost) (Fig. 3). Data for these figures are presented in Tables 1-3. Additional estimates of costs to the average firm are shown in Table 3 and include the average net annual cash flow cost and the maximum and average reduction in profit.

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[a] Another approach is to interpolate between two guidance levels for which costs have been estimated. Using the next lower cost study guidance level is more conservative, overstating the cost somewhat.

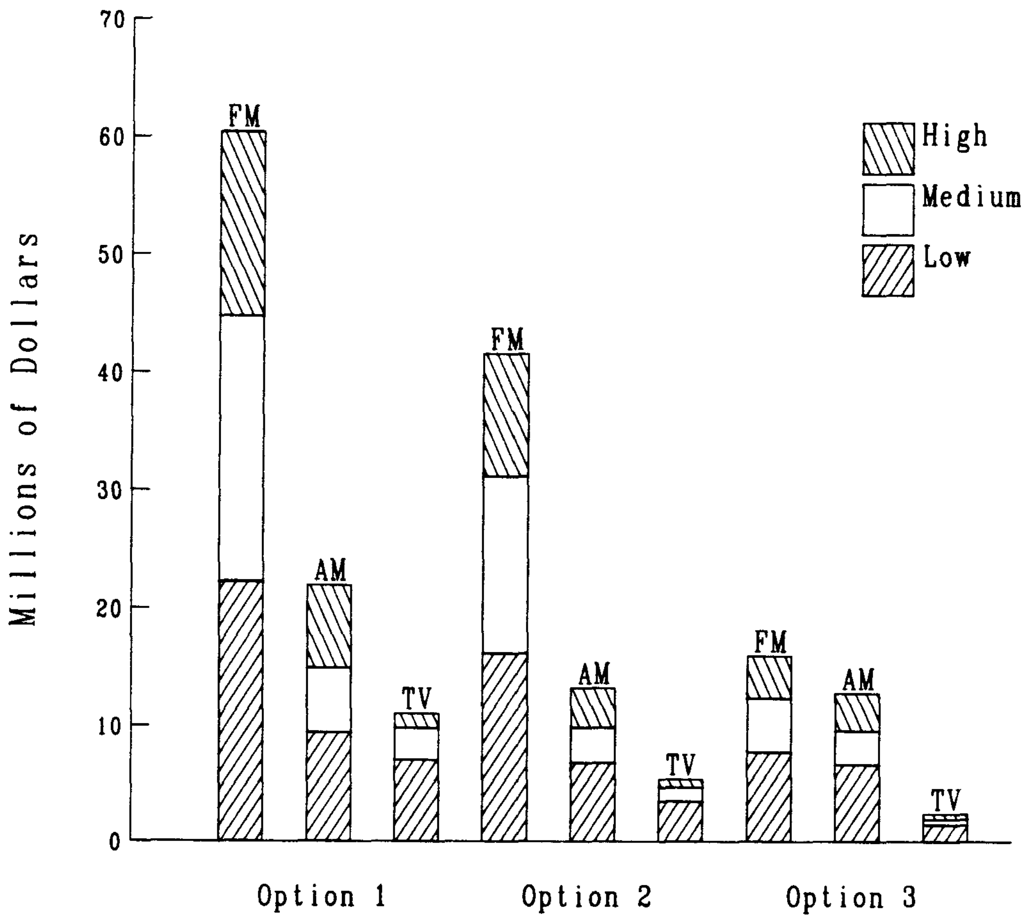

Figure 1. The range of the total present (constant dollar) value of the cost to society-at-large of guidelines limiting public exposure to radiofrequency radiation from FM, AM, and TV broadcast sources is shown for three possible guidance structures.

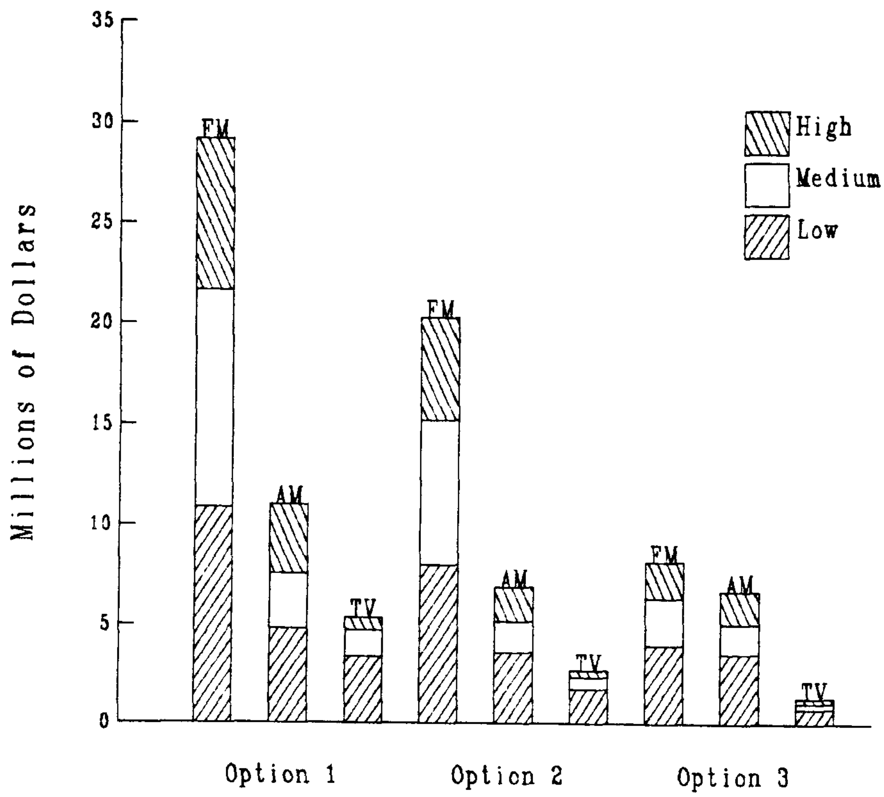

Figure 2. The range of the total present (constant dollar) value of the net after-tax cost to the broadcast industry of guidelines limiting public exposure to radiofrequency radiation from AM, FM, and TV broadcast sources is shown for three possible guidance structures.

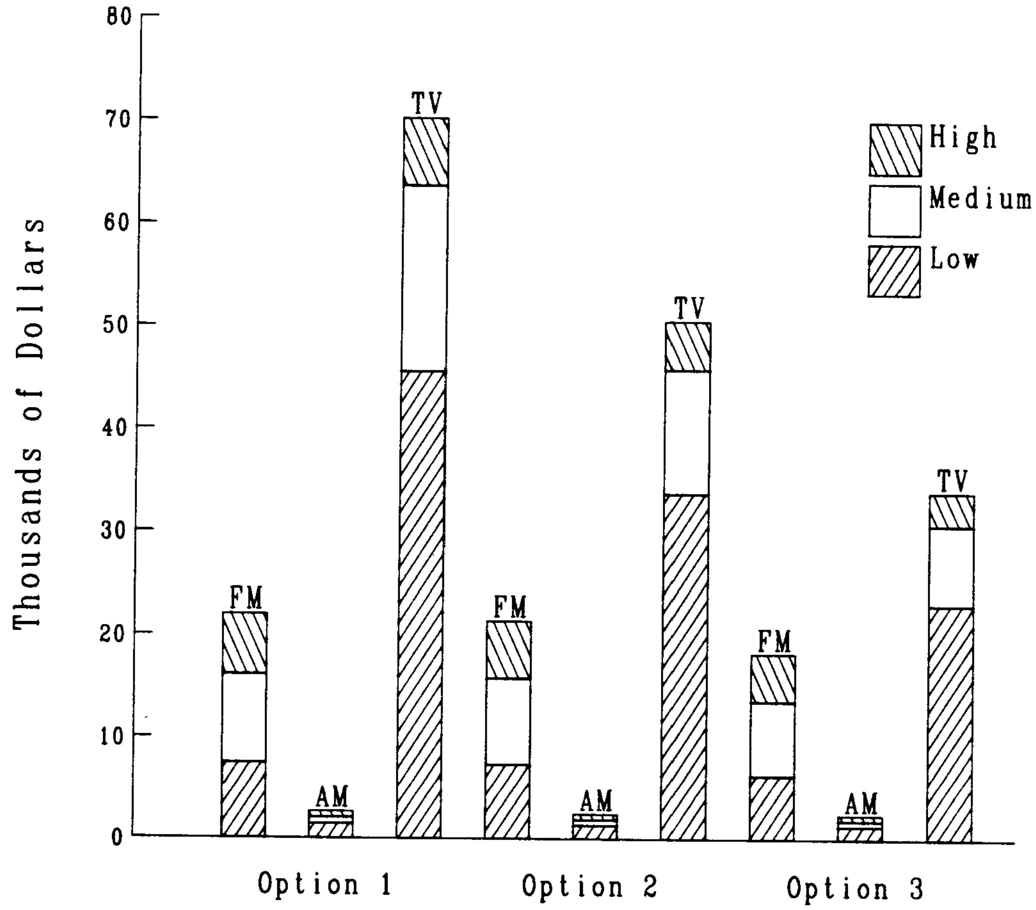

Figure 3. The range of the average present (constant dollar) value of the net after-tax cost to the average FM, AM, and TV broadcast station of guidelines limiting public exposure to radiofrequency radiation is shown for three possible guidance structures.

TABLE 1. AN ESTIMATE OF THE TOTAL PRESENT (CONSTANT DOLLAR) VALUE OF THE COST TO SOCIETY-AT-LARGE OF GUIDELINES LIMITING PUBLIC EXPOSURE TO RADIOFREQUENCY RADIATION FROM FM, AM, AND TV BROADCAST SOURCES IS SHOWN FOR THREE POSSIBLE GUIDANCE STRUCTURES. NUMBERS ARE IN MILLIONS OF DOLLARS.

	FM			AM			TV			TOTAL		
	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
ALTERNATIVE 1	22.2	44.7	60.4	9.4	15.0	22.0	7.1	9.8	11.0	38.7	69.5	93.4
ALTERNATIVE 2	16.2	31.2	41.6	6.8	9.8	13.3	3.5	4.7	5.4	26.5	45.7	60.3
ALTERNATIVE 3	7.8	12.4	16.0	6.7	9.6	12.8	1.4	1.9	2.4	15.9	23.9	31.2

TABLE 2. AN ESTIMATE OF THE TOTAL PRESENT (CONSTANT DOLLAR) VALUE OF THE NET AFTER-TAX COST TO THE BROADCAST INDUSTRY OF GUIDELINES LIMITING PUBLIC EXPOSURE TO RADIOFREQUENCY RADIATION FROM FM, AM, AND TV BROADCAST SOURCES IS SHOWN FOR THREE POSSIBLE GUIDANCE STRUCTURES. NUMBERS ARE IN MILLIONS OF DOLLARS.

	FM			AM			TV			TOTAL		
	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
ALTERNATIVE 1	10.9	21.7	29.2	4.8	7.6	11.0	3.4	4.7	5.4	19.1	34.0	45.6
ALTERNATIVE 2	8.0	15.2	20.3	3.6	5.2	6.9	1.7	2.3	2.7	13.4	22.7	29.9
ALTERNATIVE 3	4.0	6.4	8.2	3.6	5.1	6.7	0.8	1.0	1.3	8.4	12.4	16.2

TABLE 3. AN ESTIMATE OF THE POTENTIAL NET AFTER-TAX COST TO THE AVERAGE BROADCAST STATION OF GUIDELINES LIMITING PUBLIC EXPOSURE TO RADIOFREQUENCY RADIATION FROM FM, AM, AND TV BROADCAST SOURCES IS SHOWN FOR THREE POSSIBLE GUIDANCE STRUCTURES. NUMBERS ARE IN THOUSANDS OF DOLLARS.

	FM			AM			TV		
	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
ALTERNATIVE 1									
AVG ANN CASH FLOW COST	1.8	3.8	5.2	0.3	0.5	0.6	10.8	15.1	16.7
AVERAGE PRESENT VALUE	7.5	16.1	22.0	1.4	2.0	2.6	45.6	63.7	70.3
MAX PROFIT DROP (%)	3.6	7.2	9.7	1.4	2.0	2.5	1.4	1.9	2.1
AVG PROFIT DROP (%)	1.8	4.0	5.4	0.4	0.6	0.8	0.8	1.2	1.3
ALTERNATIVE 2									
AVG ANN CASH FLOW COST	1.7	3.7	5.0	0.3	0.4	0.5	8.0	10.9	12.0
AVERAGE PRESENT VALUE	7.4	15.8	21.4	1.3	1.9	2.4	33.8	45.9	50.6
MAX PROFIT DROP (%)	3.5	7.1	9.5	1.4	1.9	2.4	1.0	1.4	1.5
AVG PROFIT DROP (%)	1.8	3.9	5.3	0.4	0.5	0.7	0.6	0.8	0.9
ALTERNATIVE 3									
AVG ANN CASH FLOW COST	1.5	3.2	4.3	0.3	0.4	0.5	5.5	7.3	8.0
AVERAGE PRESENT VALUE	6.4	13.6	18.3	1.3	1.8	2.4	23.1	30.8	34.0
MAX PROFIT DROP (%)	3.1	6.2	8.3	1.4	1.9	2.4	0.7	1.0	1.1
AVG PROFIT DROP (%)	1.6	3.4	4.5	0.4	0.5	0.7	0.4	0.6	0.6

STANDARDS LIMITING EXPOSURE TO RADIOFREQUENCY AND MICROWAVE ENERGY

There is a long history of serious concern over establishing standards for occupational and public exposure and product emissions of electromagnetic, or radio wave, energy.[5] The EPA, with the absorption of the Federal Radiation Council in 1970, has assumed authority over non-ionizing as well as ionizing radiation as an environmental parameter within its jurisdiction that has potential public health risks. This parallels a number of other agencies, public and private, that have a continuing interest in non-ionizing or radiofrequency and microwave (RF/MW) radiation energy. Since 1966, the American National Standards Institute (ANSI) has issued, and conducted scheduled revisions of, both occupational and non-occupational (public) RF/MW standards, the latest in August of 1983.[6] Figure 4 shows a comparison of selected RF standards including the previous and current ANSI standards.

The National Telecommunications and Information Administration (NTIA) within the Department of Commerce (DOC) has held responsibility for coordinating non-ionizing radiation bioeffects research. The NTIA was formed in 1978 when the Office of Telecommunications Policy was transferred from the Executive Office of the President to the NTIA. However, NTIA has recently decided to discontinue its bioeffects research coordination function. Its Electromagnetic Radiation Management Advisory Council, as a result, has been disbanded. The NTIA's spectrum policy, planning, and management function under the Frequency Management Advisory Council, all basically contributing to the DOC's fundamental mission to facilitate business, trade, commerce, and industrial production, will continue. The Department of Defense has initiated a review of its own exposure standards for RF/MW radiation. The American Conference of Governmental and Industrial Hygienists is also reviewing its RF/MW exposure standard.

The Occupational Safety and Health Administration published occupational RF/MW exposure standards until a recent decision to withdraw all such voluntary advisory standards.[a] The National Institute of Occupational Safety and Health has prepared a criterion document on the occupational health effects of RF/MW that has not been made public at this time.

In the international arena, the World Health Organization has published an RF/MW health effects criteria document that contains population, occupational, and product

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[a] This decision was reversed by OSHA in February 1984 at the request of the Federal Communications Commission (Microwave News, IV(2), March, 1984).

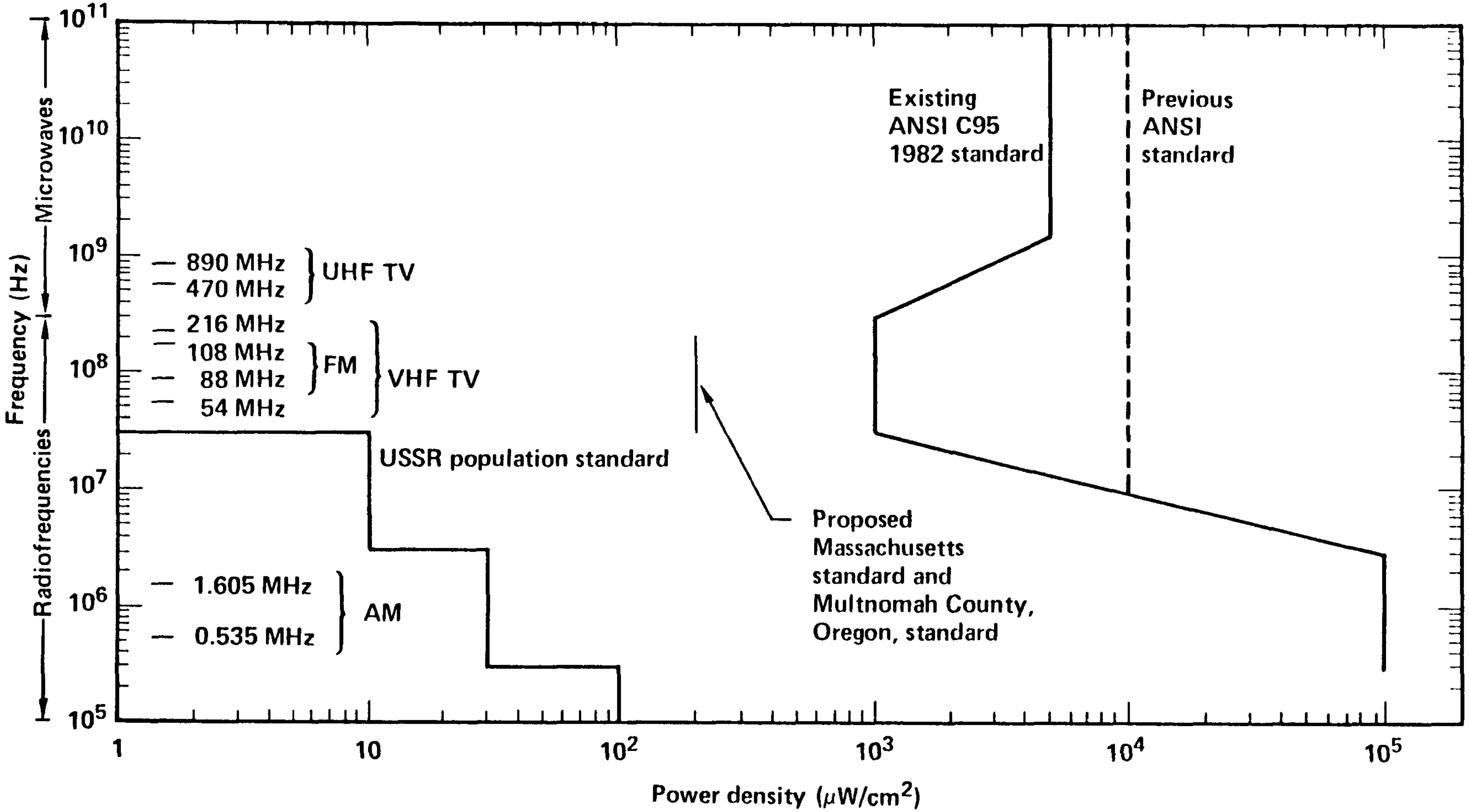


Figure 4. Radiofrequency and microwave energy spectra are shown with a number of population exposure standards.

standards, in addition to sections on implementation and further research needs. The International Non-Ionizing Radiation Committee of the International Radiation Protection Association has very recently published an occupational RF/MW exposure standard.

In the United States, the Technical Electronic Product Radiation Safety Standards Committee of the National Center for Devices and Radiological Health of the Food and Drug Administration is charged with recommending product emission standards for such appliances as microwave ovens and industrial heat sealers.

CURRENT REGULATORY EFFORTS

The Federal Communications Commission (FCC) has overall responsibility for licensing broadcast stations and maintaining acceptable broadcast/reception conditions and standards of service and otherwise regulating the broadcast industry. The FCC decided in 1979 that, under the National Environmental Policy Act (NEPA)[7] of 1969, it also had responsibility for public safety with regard to RF energy emanating from broadcast sources it is responsible for regulating. To this end, the FCC issued a notice of inquiry[8] followed by an Advance Notice of Proposed Rule Making (ANPR)[9] both of which solicited comments on the FCC's proposal to issue standards limiting public exposure to RF from regulated broadcast sources. The FCC has worked closely with the EPA, particularly the ORP, which is responsible for EPA's ionizing and non-ionizing radiation regulatory program. The EPA has also issued an ANPR[10] on its intention, in concert with the FCC, to publish a guideline limiting public exposure to RF/MW radiation. At the same time, the ORP is preparing a preliminary draft of the Federal Guidance for public exposure to RF to be implemented and administered by the various pertinent Federal agencies. An interagency work group has reviewed the Draft Proposed Guidance.[11] Further, the EPA's Office of Research and Development Health Effects Research Laboratory has prepared a draft of a health effects criteria document.[12] This draft has been reviewed by a Scientific Advisory Board (SAB) panel and has been revised at the direction of the SAB.

THE ELECTROMAGNETIC ENERGY ENVIRONMENT

Communications, entertainment, recreation, manufacturing, food processing, medicine, defense, navigation, and space exploration have all benefited from advances in the use of RF/MW over the past 40 years. The public is exposed to intermittent or continuous RF/MW sources from a growing variety of sources: AM and FM radio and television broadcasting stations; navigation and defense radar; land-mobile (citizens band, emergency services, telephone); hand-held transceivers; police traffic control radar; point-to-point, earth-satellite, and deep space microwave communications; medical diathermy; commercial and residential microwave ovens; and industrial RF/MW sealers and heaters.

Radiowaves are electromagnetic energy consisting of coupled electric and magnetic fields that oscillate at the same frequency as the source, from which they propagate outward at the velocity of light in the medium through which the energy is moving. The relationship between the frequency, f, and wavelength, λ, for electromagnetic waves is approximately as follows:

$$\lambda = s/f\,, \qquad (1)$$

where

λ = the wavelength in meters,

s = speed of light in air, meters per second, and

f = the frequency in Hertz or cycles per second.

The EM energy spectrum extends from zero to 10^{25} Hz and includes the electrical frequency (low cycles per second), radiofrequency, optical frequency, and ionizing frequency ranges. Radiofrequency and microwave radiation includes the spectrum from 3 kHz to 300 GHz, with wavelengths varying from 100,000 m to 1 mm. Microwaves are defined as the portion including the spectrum between 300 MHz and 300 GHz, with wavelengths from 1 m to 1 mm.

The RF environment includes fields from many sources and frequencies. However, two frequency bands deliver the majority of the energy to which the public is exposed, the AM radio band, 0.535 to 1.605 MHz, and the FM radio, VHF and UHF TV bands, 54-890 MHz. A report analyzing the radiofrequency radiation environment to which the public is exposed and a discussion of the RF sources responsible has been prepared by the EPA.[13]

RESEARCH ON BIOLOGICAL EFFECTS AND HEALTH RISKS OF RADIOFREQUENCY/MICROWAVE RADIATION

Research on biological effects and health risks of RF/MW evidences long-standing, widespread, and diverse concern over the possible consequences of exposure to RF/MW radiation. This research dates from at least World War II when the U.S. Naval Research Laboratory investigated the possible harmful effects of microwaves. In 1948, researchers at the Mayo Clinic documented the first hazardous effect--cataracts in dogs used as experimental subjects.[14] Soviet researchers reported behavioral and subjective symptomatic effects at about the same time. In 1953, a Hughes Aircraft Company engineer, John T. McLaughlin, documented an apparent pattern of disease among radar workers. In reaction to this development, the Navy established a temporary exposure standard for MW. In 1956, the Armed Services initiated a more rigorous research effort known as the Tri-Services Program to establish a scientifically-based RF/MW standard.[15] ANSI assumed responsibility for setting voluntary standards and has a scheduled review of its standards every five years. Subsequently, a number of federal agencies became interested in RF/MW from an occupational, public exposure, and product emission standpoint. Currently, biological effects and health risk research is being monitored, funded, coordinated, or conducted by several agencies, among them the Office of Naval Research, the Air Force School of Aerospace Medicine, Center for Devices and Radiological Health (Food and Drug Administration), the National Institute of Environmental Health Sciences, the Environmental Protection Agency, the Department of Energy, and the Naval Medical Research and Development Command (Naval Aerospace Medical Research Laboratory).

Recently, the EPA evaluated the available scientific data in a report entitled Biological Effects of Radiofrequency Radiation.[12] Although there are over 5000 citations in the literature of studies of RF radiation effects, reports were included in the document only if they met certain minimum acceptance criteria and if they could be useful in developing the basis for exposure guidelines by adequately identifying and quantifying the biological and health effects.[16]

CONCERNS OF THE BROADCAST, COMMUNICATIONS, AND ELECTRONIC EQUIPMENT INDUSTRIES

Industry concerns focus on growing public resistance to siting communication and broadcast facilities in local communities. Industry is also concerned with having to satisfy state and local RF/MW public exposure standards that may be established at different levels that may be unnecessarily stringent because these agencies lack the facilities or funds to conduct the necessary scientific studies on which to base carefully designed standards. However, state and local officials feel compelled to respond to constituencies that express a growing perception of health risk from RF/MW exposure. Electronic equipment manufacturers are also concerned over product emission safety standards, a subject which this economic study does not address.

Numerous companies and industrial organizations have urged the EPA and FCC to adopt RF/MW standards in hopes of allaying public fears of perceived health risks. Among these are the American Telephone and Telegraph Company, American Satellite Company, GTE Service Corporation, TV Broadcasters All-Industry Committee, National Association of Broadcasters, Association for Broadcast Engineering Standards, Columbia Broadcasting Systems, Motorola Corporation, American Radio Relay League (Amateur Radio Organization), Doubleday Broadcasting, and even state and local officials who must address citizen concerns over RF/MW exposure.[17]

The public's growing perception of the risk of health hazards from RF/MW is causing increasing local opposition to the siting of communication and broadcast facilities, according to a communications and electronics research/industry newsletter.[18] This opposition appears to have originated with the rejection of Home Box Office corporation's application for a communications satellite (comsat) facility by Rockaway Township, New Jersey. Subsequently, RCA Americom was denied permission to build a comsat facility on both Bainbridge Island and in Indianola-Kingston (Kitsap County), Washington. The Port Authorities for New York and New Jersey and Merrill Lynch Pierce Fenner and Smith are proposing a teleport facility on Staten Island in the face of public opposition. Filmways Communications has been denied permission to build a television broadcast station in Onondaga, New York. U.S. Telecommunications Systems (an ITT subsidiary) was denied a permit to build a microwave relay station in Coventry, Connecticut. World Christian Broadcasting Corporation is facing severe opposition to its proposed shortwave station in Anchor Point, Alaska. Vernon, New Jersey, denied RCA Americom permission to build a microwave relay uplink station for its satellite communication center. Alascom Corporation is facing opposition to a comsat facility on Vashon Island (King County), Washington. ITT Corporation has been denied permission to build a point-to-point microwave relay station in South Nyack, New York, and faces organized opposition to its alternate site proposal for Ringwood, New Jersey. Group W Satellite Communications Corporation is facing opposition organized by the Citizen's Action Group to a comsat facility in Stamford, Connecticut. There has been long-standing opposition to the Navy's installation of large antenna systems required by its submarine communication system (known successively as Project Sanguine, Seafarer, and now, ELF) in Clam Lake, Wisconsin, and K.I. Sawyer Air Force Base in Michigan. Recently, the Coast Guard faced opposition to an OMEGA radar antenna facility in Hawaii. In addition, there is a growing body of litigation concerning alleged health effects of exposure to RF/MW.

In response to public fears of perceived health hazards from RF/MW, a number of state and local agencies have initiated studies and several are in the process of, or have adopted, RF/MW public exposure standards. Among the latter are Multnoma County, Oregon, the states of New Jersey, Conneticut, Wisconsin, Massahusetts, Texas, and

Arizona, and the cities of Portland, Oregon and Onondaga, New York.[19] Industry is concerned about technical compliance with differing local standards involving an energy medium that is difficult to control with respect to jurisdictional boundaries. Federal, state, and local government agencies are concerned about enforcement difficulties in a regulatory environment of multiple RF/MW public exposure standards.

The electronic equipment manufacturing industry is further concerned with the growing volume of litigation dealing with alleged health effects from products including microwave and radar antennas, microwave ovens, and video display terminals.

PURPOSE OF STANDARDS LIMITING PUBLIC EXPOSURE TO RADIOFREQUENCY/MICROWAVE ENERGY

The EPA, observing the conjunction of numerous forces, including long-standing scientific interest in the biological effects and health risks, increasing public perception of health hazards, industry concern over siting, the desire for consistency among differing local and state standards, and increasingly vocal opposition and litigation, is completing research necessary to establish a standard limiting public exposure to RF/MW radiation. The research is comprehensive in scope, including health effects, cost studies, field measurements of the electromagnetic environment, signal propagation studies, and studies of the efficacy of a wide variety of compliance measures, some of which have been designed and modeled during the course of this research.

PROFILE OF BROADCAST FACILITIES

The broadcast industry is large and growing, as the following statistics reveal;[20] total assets in 1980 were $5.5 billion, about 65% of which is in the TV industry. The total industry employs about 126,000 people who earn an aggregate wage of $3.1 billion. Industry gross revenues were about $12.0 billion (73% TV); net (after taxes) income was $1.8 billion (92% TV). In the decade 1971-1981, the number of FM radio stations increased by 47%, AM stations by 8% and TV stations by 11%. A general reason for this growth is seen in a study of the number of trillion words transmitted by public media.[21] This study tracked trends in the volume and cost of words transmitted by 17 media. More words were transmitted by radio (AM and FM) and were the least costly of any of the media. Radio and television grew in number of words transmitted and in reduction of cost by about the same percentage over the period of 1960 to 1977; however radio continues to transmit about 3-1/2 times as many words (5.5×10^{17}) as TV at one tenth the cost per word (\$3.0 x 10^{-9}).[a] Of the voice communication media, as distinct from data communication, CATV grew twice as fast in number of words produced over the same period but transmits almost 20 times fewer words than TV at ten times the cost per word.

The physical facilities of an FM radio station vary but typically include a broadcast studio/office, from which the program content is assembled for transmission (Fig. 5). The broadcast antenna is often located on a tower at the studio site. If so, the broadcast material is conveyed over wire directly to the transmitter, which provides the power to the antenna. Power from the transmitter is usually conveyed to the antenna via a coaxial transmission line and fed to each element of the antenna (called a bay) through an electrical coupler or feed system that distributes and phases the signal for each bay. A studio-transmitter-link is used to broadcast the program material to the transmitter-antenna when the latter is remote from the broadcast studio.

Antenna signal patterns are routinely "tuned" or shaped to avoid interference with another station's signal, to direct the signal to the greatest population, to fill in nulls or poor reception areas, or to avoid broadcasting a signal to non-market areas, the ocean, for example. The signal shaping is accomplished in different ways for AM, FM, and TV. The factors for all three, though, involve the geometry of the element design, spacing, and placement, tower design and geometry, and signal phase control.

A broadcast station is a complex interaction of several forces that together result in the public image of a station that is dynamic, fluid, and curiously life-like as few other organizations are. The owners/partners/ managers bring the entrepreneurial spirit to the enterprise. Before the expansion of the FM car stereo market, this often flew in the face of continual losses and required a dedication to a particular type of programming and character of station, e.g., classical or jazz music.

The FM broadcast industry is undergoing a period of rapid change and expansion that began about a decade ago, spurred by expanding FM audiences. The enormous increase in FM listeners is the result of a conjunction of three trends. First, there have been significant improvements in the quality of recording, transmitting, and receiving equipment that have raised the standards and expectations of listeners for high quality sound, particularly for music. Second, good FM receivers are now widely available as standard equipment, dealer-installed option, or after-market installation for automobiles. This brings job-holding commuters--key targets of radio advertising campaigns--into the prime 6-9 a.m. listener period, greatly increasing the potential advertising revenue for FM

[a] 1972 dollars.

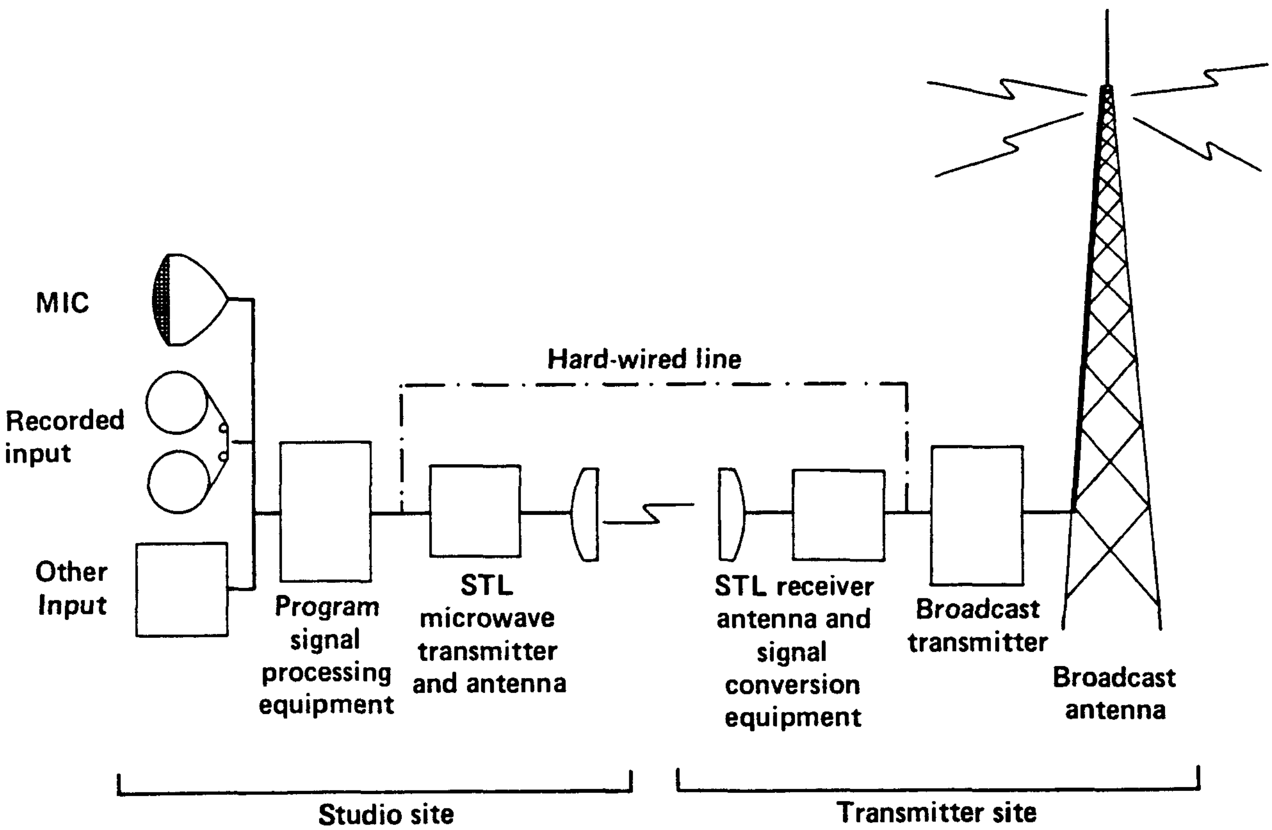


Figure 5. The elements of a broadcast system are shown with the ultimate signal carried from the transmitter via coaxial cable and broadcast from the antenna, which is insulated from the tower. FM radio, VHF-TV and UHF-TV antenna systems are similar. AM antenna systems differ in that the whole tower is used as a signal radiating element; the tower is electrically grounded with a system of radial copper wires.

radio stations. Third, FM programming, following the growth in audiences and advertising revenues, has greatly diversified and expanded. FM stations air a wide variety of programming and they also segment the listener market into increasingly smaller, specialized fractions. One result of this growth is that the market price for FM stations has jumped by as much as a factor of 10 in the past decade.

With the growth in the FM market and the tremendous surge in the cost of FM stations, there is a greater emphasis on the balance sheet. In 1971, 35% of independent FM stations reported a profit; in 1980, 50% were profitable.

The rapidly inflating market prices for FM stations, a function of the growth in FM listenership, the increasing scarcity of good broadcasting sites in lucrative markets, and tax laws have created a situation in which market appreciation and realization of income taxed at lower rates, e.g., long term capital gains, assume dominant importance. This accounts, partly, for the fact that 50% of independent FM stations tolerate operating losses in the current economy.

A station's value is not solely a function of current earnings, market share, audience size, or gross revenues. A major factor is potential earnings, which are primarily a function of potential audience size and demographic description of the population in the region. The area of dominant influence, usually larger than the FCC-defined market area, is influenced by two factors: signal strength, and audience draw (determined chiefly by the underlying demography of the potential audience and the programming). If the potential audience is sufficiently large and has the appropriate demographic profile, a station's market share can often be increased by changes in programming.

The programming function really establishes the character and image of the station with listeners. Station images have become fairly standardized; the industry uses commonly understood image or market categories such as easy listening, rock and roll, country and western, soul, jazz, classical, talk, and top 40 to report sales and revenue statistics, demographic and market trends. According to programming specialists, the type of programming is probably the most significant determinant of the demographic description of a station's listener audience.

The engineering people keep the station on the air and design or hire consultants to design new equipment configurations. Engineers emphasize the importance of maintaining maximum power to saturate the audience and keep the signal quality high. In fact, the FCC requires stations to maintain a minimum signal strength of 60 dbu (1.0 mV/m) over the broadcast coverage area and 70 dbu over the city of license.

The marketing and sales staff sell advertising time, which is the sole source of revenue for a station. Generally, radio advertising is a relatively inexpensive way to reach a wide audience. However, the marketing people also like to emphasize a station's power or height of antenna or size of market to attract advertisers. Stations generally like to maintain a balance among the three sources of sales revenues: national, regional, and local. Small stations tend to rely on national sales representatives and the size of broadcast coverage area (area and population) rather than on ratings to sell national time.

The radio personalities convey the station image and character along with the programming and can greatly influence listener audience share and advertising revenues. Programs and radio personalities are continually rated by one of the audience sampling services. The rating and audience share influence ad rates for a show, time segment or station. Hence, the competition for high ratings and shares is intense, especially in competitive radio markets such as Los Angeles, New York, and San Francisco.

Radio stations, with all of their dynamic elements, operate within the regulatory framework maintained by the FCC. The FCC is generally responsible for assuring that each station has an interference-free broadcast coverage area. This is accomplished by regulating the effective radiated power (ERP), which is a function of transmitted power and antenna gain; antenna height; and geographic separation from other stations. Recently, the FCC has been affected by a general move in the federal government toward deregulation of industries; as a consequence, there may be some deregulation of the broadcast industry in the future.

When a station applies for its first license to broadcast or applies for a permit to change its broadcast components, a wide variety of permits, each with its underlying engineering study is necessary. These may include a mileage separation, field strength, and population density study. The Federal Aviation Administration (FAA) requires a permit and accompanying study for many tower installations. Many of these studies are required as part of the compliance measures discussed further in this report. In addition, local jurisdictions require studies supporting land use permit and zoning applications.

Other changes affecting the broadcast industry include the planned introduction of AM stereo, cellular radio, high-definition television, and low-power television. These are not expected to have any influence on the RF environment to which the public is exposed.

Television stations are more capital intensive than FM stations; expenses are higher but the potential profits are very high, particularly in large metropolitan markets. The series of photographs (Figs. 6-9) show studio and transmission facilities of FM radio and

Figure 6. Material is broadcast live, prerecorded, or recorded live from the field.

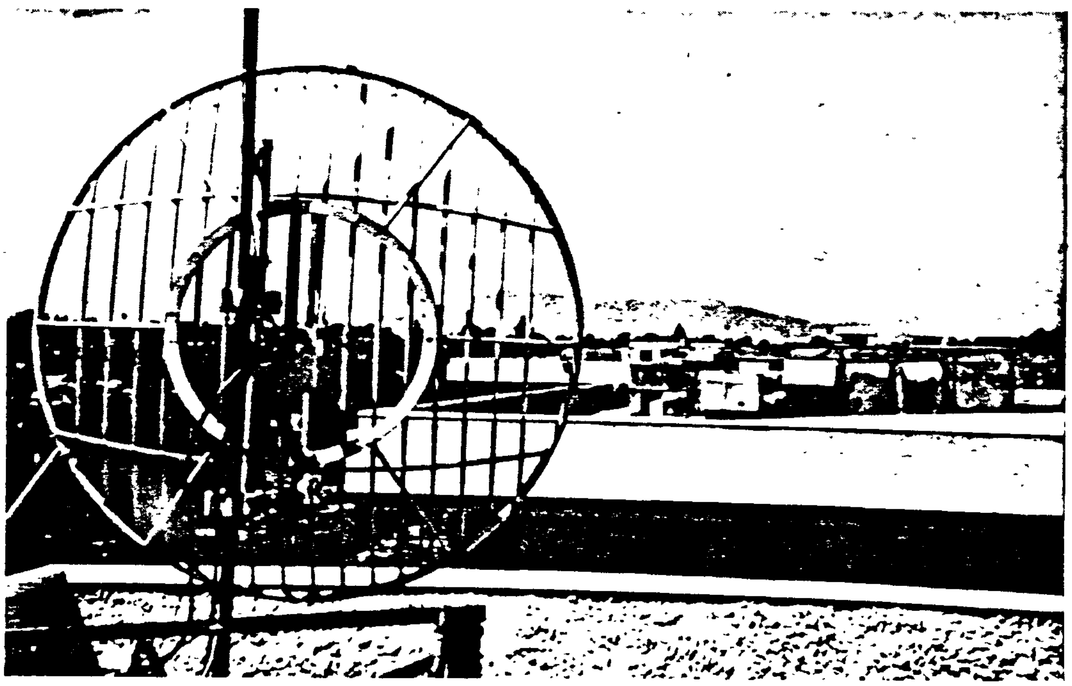


Figure 7. The signal is conveyed from the studio to a remote broadcast tower via a microwave studio-transmitter link.

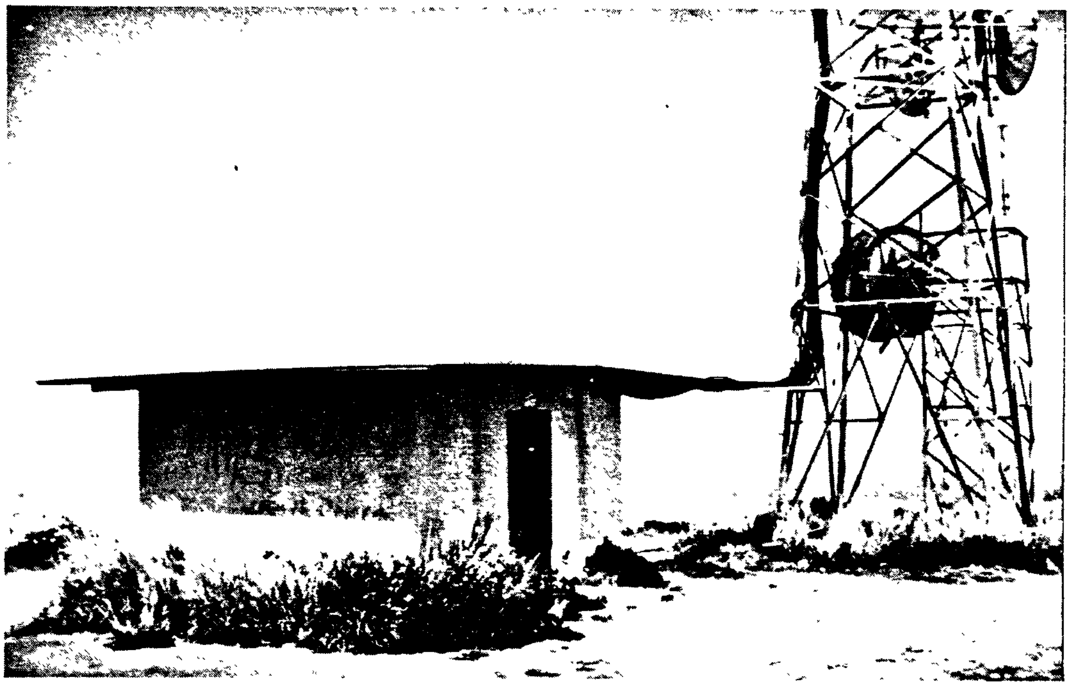


Figure 8. The studio-transmitter signal is received by a microwave dish antenna, converted to broadcast power at the transmitter, and fed to the broadcast antenna via coaxial cable.

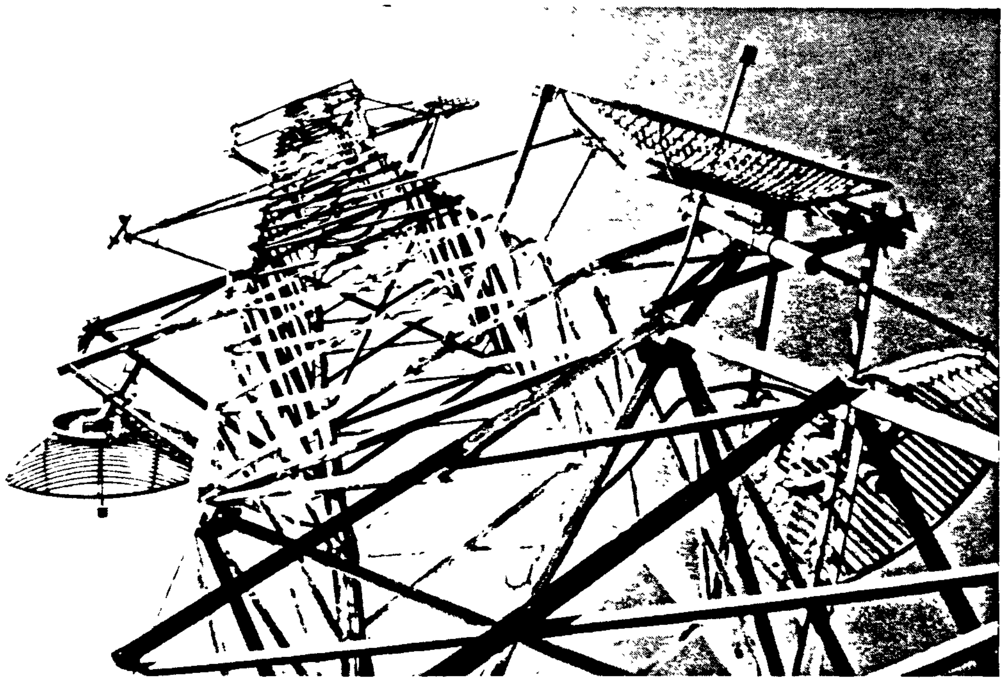


Figure 9. The coaxial cable feeds broadcast antennas on the tower (not visible above the catwalk).

television stations. Sutro tower, in San Francisco (Figs. 10-12), is a sophisticated system serving a number of television and FM stations and private land-mobile systems. An AM system is shown in Figs. 13-14.

AM radio station antennas typically have a configuration similar to that shown in Fig. 13. These antenna systems do not lend themselves easily to modification as do FM and TV antennas. Therefore, prohibiting public access by fencing the area near the antenna that is exposed to RF over-standard was used as the compliance measure for those AM stations that required some form of mitigation. Figure 14 shows a three-tower AM antenna system.

FRAMEWORK FOR THE ECONOMIC STUDY

Cost-benefit analysis (CBA) dates from the 1844 publication of an essay, "On the Measurement of the Utility of Public Works," by Jules Dupoit.[22] Dupoit conceived the notion of consumers' surplus, which is related to the concept of willingness to pay, and net social benefit, cornerstone principles of CBA.

More recently, the United States Flood Control Act of 1936 required that benefits of federal projects should exceed costs.[23-24] Thereafter, most federal public works agencies, notably the Corps of Engineers, used CBA to assess project worth throughout the next 40 years. Since the 1960's, especially following the enactment of NEPA in 1969, many statutes have been adopted that require some form of formalized decision making that balance beneficial and adverse effects or financial and social impacts.[25] During the Ford Administration, two EOs were promulgated requiring some form of economic balancing calculus.[26] President Carter further formalized these requirements in EO 12044,[27] which defined the threshold size of federal projects requiring analysis and the requirement for a regulatory analysis. This EO was supplanted by President Reagan in EO 12291,[28] which clearly identifies maximization of net social benefits as an objective of regulation. The EO mandates a Regulatory Impact Analysis for every major rule, defined as any regulation that is likely to result in:

1. an annual effect on the economy of $100 million or more;
2. a major increase in costs or prices for consumers, individual industries, federal, state, or local government agencies...; or
3. significant adverse effects on competition, employment, investment, productivity, innovation...[29]

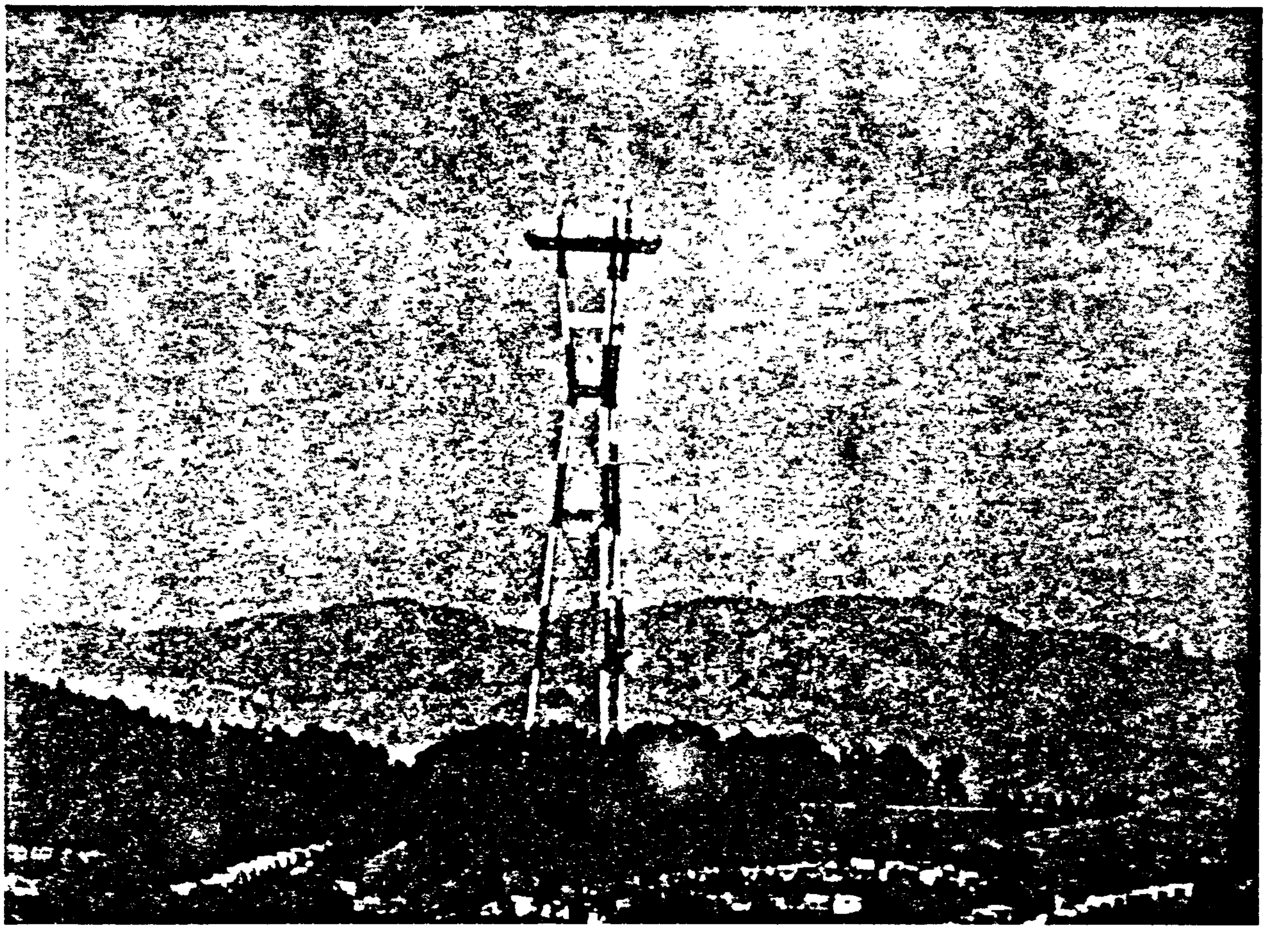
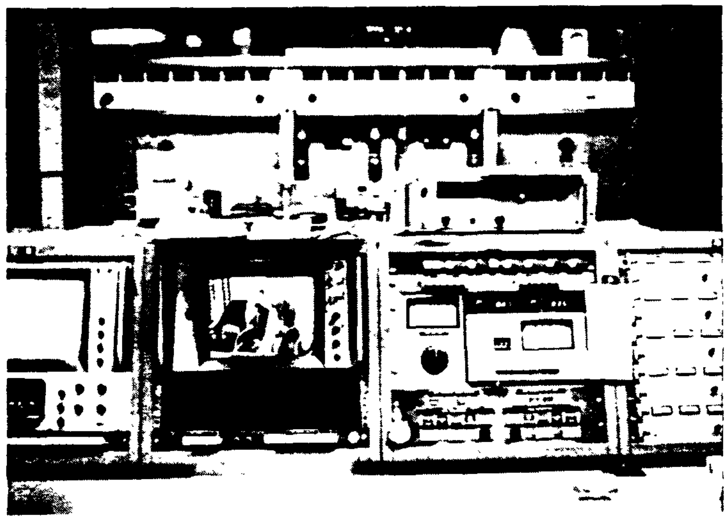
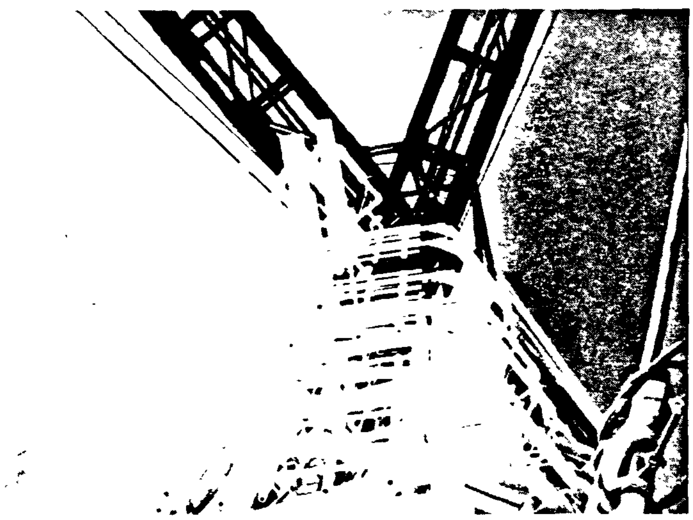


Figure 10. A sophisticated broadcast antenna system, such as this one in San Francisco, accommodates a number of television and FM broadcasters and land-mobile users. The tower is 977 feet above a hill that is 834 feet above sea level.

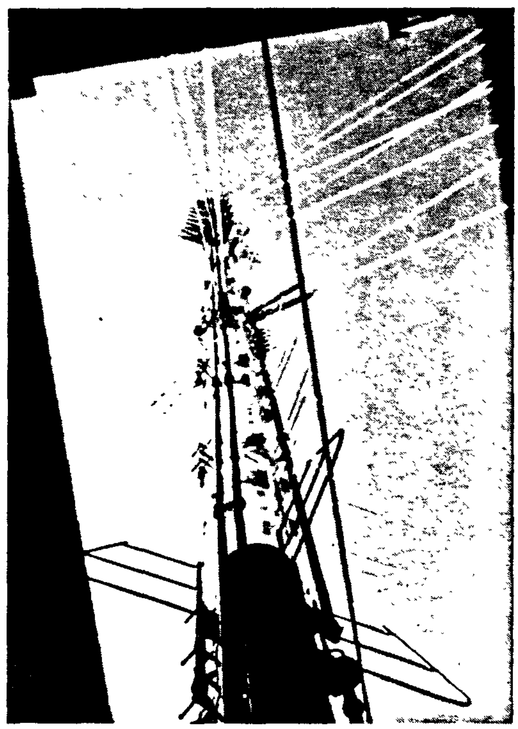
a. Microwave antenna.



b. Television transmitter and monitor.

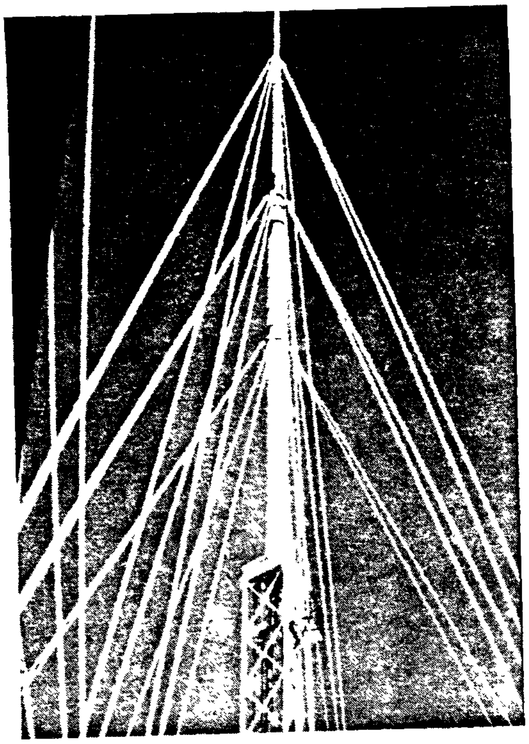


c. Circularly-polarized antenna.

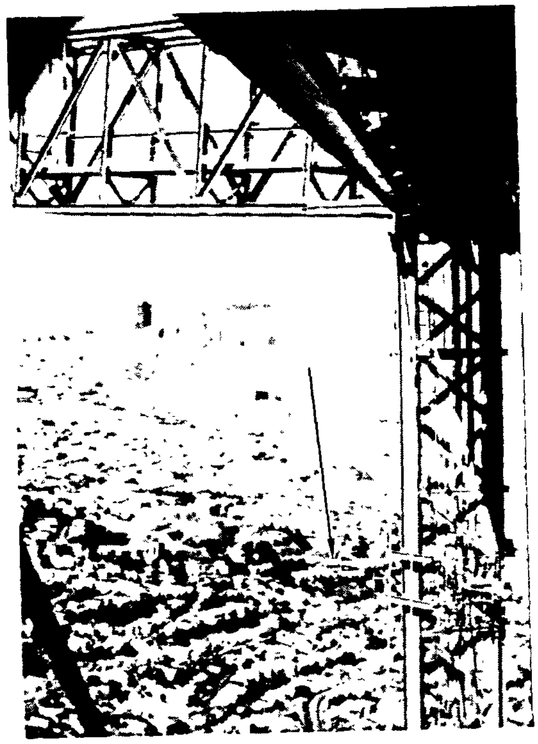


d. Batwing superturnstyle antenna.

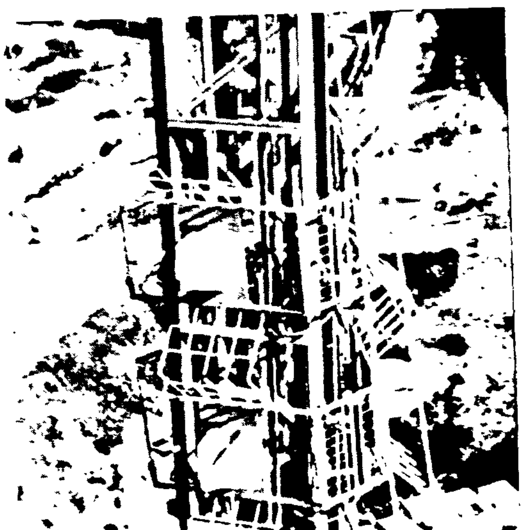
Figure 11. The large tower system in San Francisco accommodates a variety of antennas and includes sophisticated transmitter-monitoring systems.



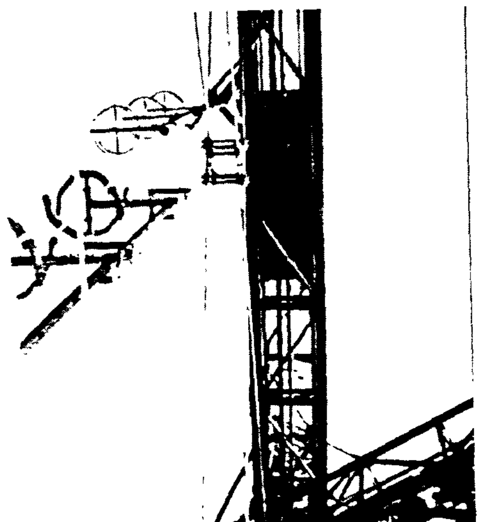
a. Traveling wave slotted antenna (very top of mast).



b. Circularly-polarized antenna (1/3 up left side of tower leg).



c. Antennas protected by radomes.



d. Circularly-polarized television antennas.

Figure 12. The large tower system in San Francisco serves additional antennas.

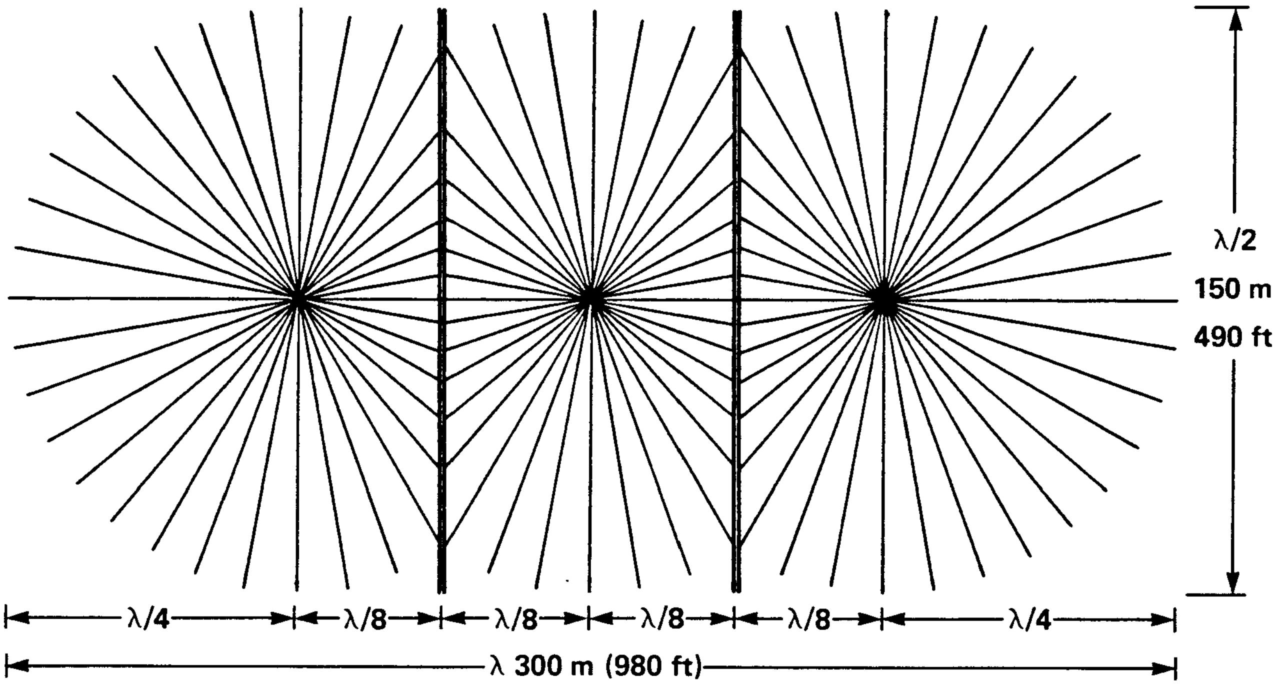


Figure 13. Typical AM antenna ground field (broadcast frequency = 1000 KHz).

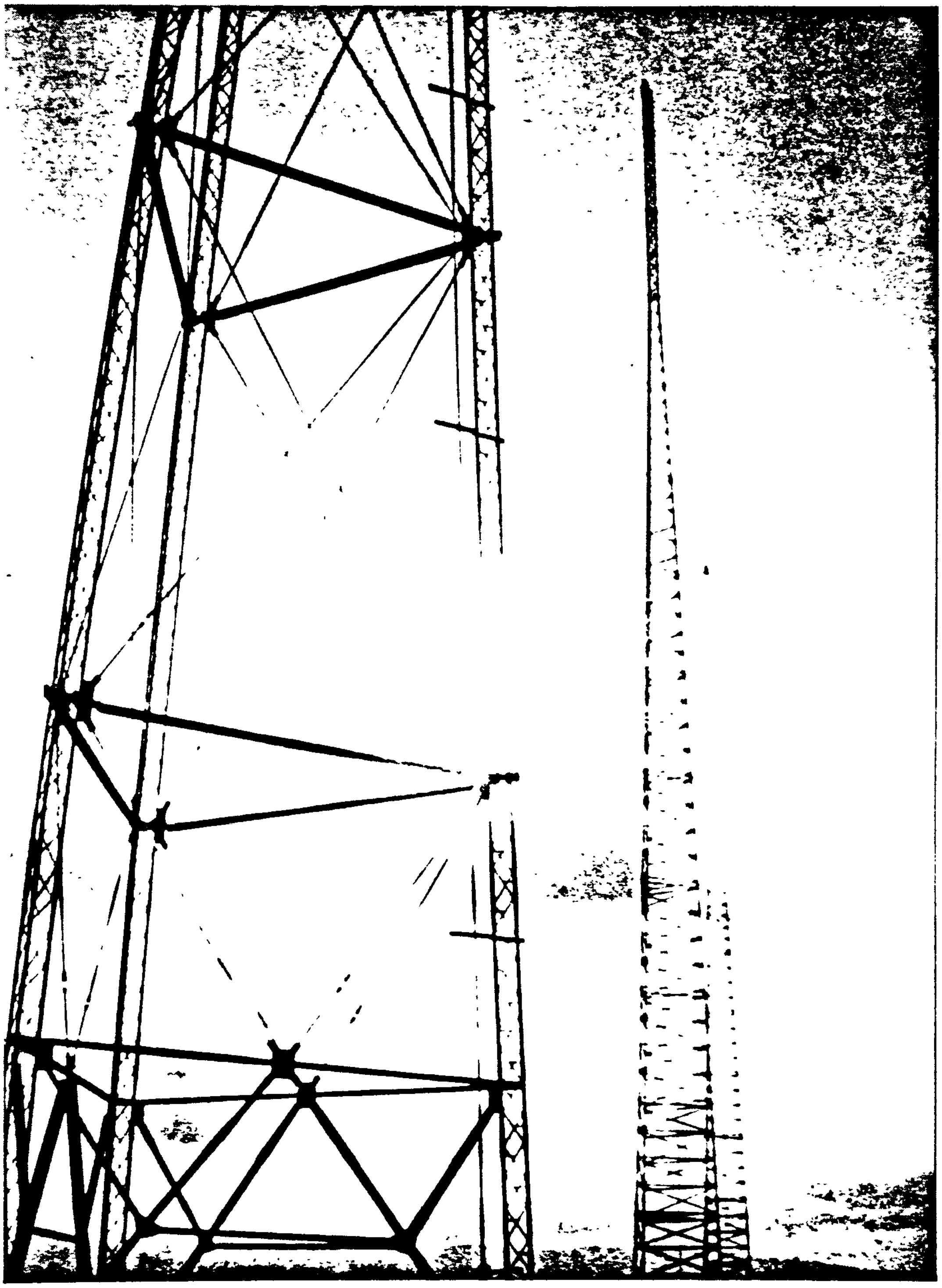


Figure 14. AM radio broadcast antennas are typically located in flat terrain with good ground conductivity characteristics. Each tower is grounded with a system of buried copper wires; the entire tower functions as the broadcast antenna.

Regulatory Impact Analyses are to contain the following information:

1. a description of the potential benefits of the rule...;
2. a description of the potential costs of the rule...;
3. a determination of the net benefits of the rule...;
4. a description of alternative approaches that could substantially achieve the same regulatory goal at a lower cost...[30]

In response, the OMB issued a memo to federal agencies that reiterated the substance of EO 12291 and ampilified portions of it, notably the definitions of alternatives to be considered, costs, benefits, and net benefit.[31]

The EPA drafted an extensive regulatory impact analysis guide, which, together with its four appendices, establishes the EPA's policy response to EO 12291.[32] This guide discusses in detail suggestions for documenting the need for the action; considering of alternative actions; considering benefits, including health and non-health effects; costs to society-at-large (opportunity costs of using resources for a selected purpose at the exclusion of other purposes); and net benefits.

METHODOLOGY

The following is a description of the approach used in this study. The general procedures, data bases, compliance measures and their selection, pre- and post-compliance RF propagation models, social, industry, and individual firm models are outlined. Figure 15 illustrates the relationships among the components of the method of approach.

With reference to Fig. 15, EPA's ORP, as a result of research over the past 12 years, has developed models that estimate the RF in terms of electric field strength and power density of the 10,000 AM and FM radio, VHF-TV and UHF-TV broadcast stations in the U.S. The models use data developed by the EPA from FCC engineering files, research results, and other sources to estimate the current RF environment resulting from the broadcast activities of the stations. To facilitate efficient modeling of the large number of FM radio stations, they were divided into groups with similar antenna design and mounting characteristics. AM radio stations were divided into groups whose antennas expose similar areas to a given intensity of RF. TV broadcast stations were analyzed individually. Stations whose RF is estimated to exceed one of the 18 alternative guidance levels studied are assigned the least costly compliance measure, selected from a series of increasingly complex, costly and effective measures, developed as part of the research for this cost study, that will effect compliance. When a compliance measure is estimated by the model to achieve compliance for a station or group of similar stations, it becomes the basis for the cost input to the three cost models. The cost models produce a variety of cost estimates for three kinds of economic analyses of each of the 18 guidance levels studied using three levels of costs for compliance measures.

ENVIRONMENTAL PROTECTION AGENCY RADIOFREQUENCY RADIATION RESEARCH

Over the past decade, the EPA has been conducting research to define the RF/MW environment to which the public is exposed.[33-39] This has been an extensive research effort that provides the foundation for defining the current RF conditions and identifying potential areas and sources of RF that further research might document as posing a health risk. In the course of these investigations, the EPA has measured the RF field strengths in almost 500 sites in the U.S. in a wide variety of environments and distances from broadcast sources.[40-42] These studies show that 99% of the urban population is exposed to less than 1 $\mu W/cm^2$ of RF (the lowest level considered in the cost study); the median exposure is one-half percent of this small value.

Studies were also conducted of traffic control, ground and airborne radar systems. Traffic radar broadcast systems studied produce less than 1 $\mu W/cm^2$ at distances from the units that people would normally be found. The maximum power density produced is 3.6 mW/cm^2 at 9 cm (3.6 in) from the antenna.[43]

Air traffic control radar systems studied in the San Francisco Bay Area showed a maximum exposure of 1.1×10^{-3} $\mu W/cm^2$,[44] indicating that this source is also below levels being considered for the guideline. In another study, the power density of aircraft-mounted radar systems was measured. Exposures of up to 10 mW/cm^2 at 8 to 18 feet horizontally from the aircraft radar unit were measured[45] (10 mW/cm^2 is the 1966 ANSI C95.1 standard). However, commercial aircraft radar units are generally over 6 feet above the ground (the height of persons on the ground).

Another study was conducted of RF in and on the roofs of tall buildings in proximity to broadcast antennas. Eight buildings were surveyed in five cities across the country. No interior area was found to have an exposure greater than 100 $\mu W/cm^2$; several roof locations,[46] to which the public does not normally have access, were exposed to levels between 100 and 200 $\mu W/cm^2$. One roof location exposure was found to be 230 $\mu W/cm^2$. It was found that mylar film used as a solar reflector is very effective at attenuating RF and could offer a low-cost means to reduce RF in buildings, if this were necessary.

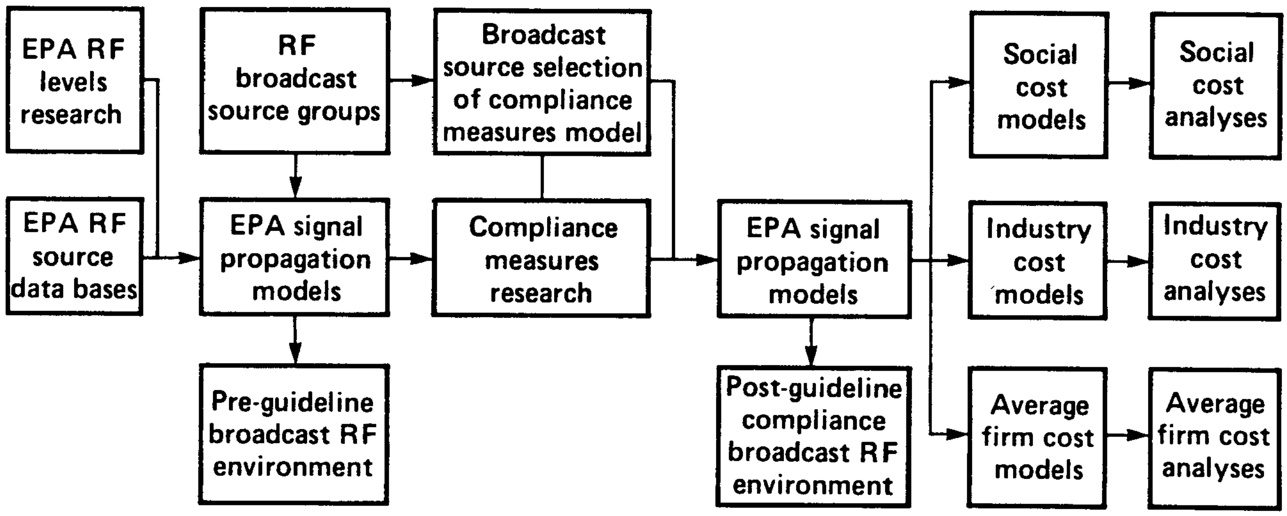


Figure 15. The general method of approach combines the output of data bases, physical signal propagation models and the application of compliance measures to social, industry and average firm cost models.

The studies of exposure from radar and inside buildings, together with the extensive studies of general population exposure to RF have lead the EPA to concentrate on commercial broadcasting and, in particular, FM radio as the chief source of public exposure to RF in the environment.

ENVIRONMENTAL PROTECTION AGENCY DATA BASE

The EPA has spent considerable time over the past three years assembling a comprehensive data base on the most critical RF sources from a guidance viewpoint: AM and FM radio and VHF- and UHF-TV stations. This data base identifies each station by call letter, city and state, corporate name, address of studio, geocoordinate location of the transmitter and antenna, and a description of broadcast engineering characteristics such as ERP, antenna type, make and model, number of elements, gain, type of mounting, height above average terrain (HAAT), height of antenna above ground, transmitter power, and others. These data are the basis for the signal propagation modeling performed by the EPA.

RADIOFREQUENCY RADIATION SOURCE GROUPS

There are approximately 4400 FM, 4600 AM, and 1100 TV broadcast stations in the United States. Each station represents a unique physical, topographic, equipment, financial, corporate structure, market, and engineering situation. Antennas are of a variety of configurations and design. They are mounted on a variety of towers, from telephone poles to very tall self-supporting towers. Some towers are located on flat terrain, some on mountain tops, some on building roofs. Most antennas are located alone on a tower; however, some FM and TV antennas are co-located on the same tower. A few FM antennas are designed so that several stations can broadcast simultaneously from a single antenna.

The FCC recognizes three geographic zones with different technical requirements and regulatory rules that accommodate the regional differences in physical and marketing environments.

The FM stations were partitioned into four groups on the basis of gross similarity in antenna mounting, which influences the power density pattern and technical solutions available for complying with standards.

Of the 4400 FM broadcast stations, the EPA data base contained information on about 3900. An adjustment was made in each group on the basis of the existing distribution to reflect the actual number of stations. These were partitioned according to the following antenna mounting methods.

1. FM stations with antennas mounted alone on a tower (guyed or self-supporting) whose base is on the ground (SFMT).
2. FM stations with antennas co-mounted with one or more other antennas on a tower (guyed or self-supporting) whose base is on the ground (MFMT).
3. FM stations with antennas mounted alone on a mast or tower whose base is on a building (SFMB).
4. FM stations with antennas co-mounted with one or more other antennas on a mast or tower whose base is on a building (MFMB).

The SFMTs and MFMTs were analyzed without modification. However, except for survey costs, the SFMBs and MFMBs were not included in the cost estimate for several reasons. Antennas mounted on masts or towers on building roofs are generally in areas of relatively high population density. However, the two major paths of public exposure to high field strengths are very rare occurrences. The first path is the exposure of people on the roof. Except in rare instances, the World Trade Center in New York, for instance, the public does not have access to building tops on which antennas are mounted. The other major public exposure path involving roof-mounted antennas is the exposure of people in nearby buildings, particularly in situations in which the RF waves are transmitted horizontally from an elevation identical to people in an adjacent building. Buildings attenuate RF significantly and levels measured inside structures adjacent to FM broadcast antennas are relatively low, typically below 50 $\mu W/cm^2$ and are not known to exceed 100 $\mu W/cm^2$.[46]

Where there is an antenna on a roof top adjacent to a new building that is taller than the antenna mast, exposure of occupants in the new building to the main signal beam is possible. However, the presence of the new building significantly degrades the signal coverage of the station's listener market. This is particularly true of FM because the physical characteristics of FM waves cause them to reflect easily off obstructions. Therefore, FM stations whose broadcast signals have been blocked by new construction are strongly motivated to relocate their antennas, often to the roof of the new building. If this location is not available, stations attempt to lease space on an existing tower or build a new tower elsewhere. Recently, towers that have been shadowed by new buildings have been moved to different locations in Houston where antennas were relocated from One Shell Plaza to a tower. Antennas were moved from the Biscayne Bay Building in Miami to a TV tower when a taller structure shadowed them. Therefore it is assumed for this analysis that FM antennas mounted on masts or towers on rooftops will not require modification to comply with RF guidelines.

The EPA data base is complete with respect to all AM broadcast stations. There is a basic similarity in the configuration of AM antenna systems, rendering only one compliance measure appropriate. The AM stations were segmented according to the distance from the tower that is exposed to RF exceeding the specified field strength level.

Television stations were analyzed individually because the prominent differences among stations, such as the broadcast frequency band (VHF or UHF), ERP, and whether the antenna is single- or co-mounted with other TV antennas on the same tower, all influence the choice of technical measures for compliance with a guideline. Furthermore, the fewer number of TV stations made individual analysis relatively easy to do.

ENVIRONMENTAL PROTECTION AGENCY BROADCAST SIGNAL PROPAGATION MODELS

Over the past 5 years, the EPA has been developing and refining models of AM, FM, VHF-TV and UHF-TV antenna wave propagation[47] from monopole and dipole configurations of various sizes. These models calculate the horizontal and vertical polarized components of the signal and grating lobe and compute exposure in V/m and $\mu W/cm^2$ at any height above ground and distance from the antenna.

The data in the EPA data base were used, together with antenna performance characteristics, as input to model the strength of signals broadcast from every radio and television station in the data base. The models have been calibrated by independent field measurements at a variety of broadcast sources. The models identify stations that will probably exceed various specified field strengths or power density levels. They also estimate the distance from the tower that the values are exceeded.

RADIOFREQUENCY RADIATION GUIDELINES

Because the final values at which the guidance will be set were not known at the time of this study, all cost analyses were performed for 18 different possible guidance levels. This approach has the advantage of revealing the variations in cost as a function of guidance level over a wide range of possible standard levels.

The AM radio RF guidance is presented in V/m, ranging from 10 V/m to 1,000 V/m; the FM radio, VHF-TV and UHF-TV broadcast RF guidance is presented in $\mu W/cm^2$, ranging from 1 $\mu W/cm^2$ to 10,000 $\mu W/cm^2$. A frequency-dependent standard reflects the approach used in existing radiofrequency standards in the United States and other countries. Figure 16 shows a shape and limiting values for a typical guidance level. Note that the curve is flat from 30 MHz to 1 GHz. Many existing standards begin an upward ramp at about 300 MHz similar to that shown in Fig. 17. EPA's proposed guidance may also incorporate a ramp, but the exact shape was not established at the time of this study. The shape which was chosen for this study represents the most conservative approach which might be chosen by EPA. If a portion of the flat region which extends from 30 MHz to 1 GHz were changed to a ramp shape, the resulting impact of the guidance on UHF stations would be reduced from the values predicted in this analysis. The limiting values of the 18 guidance levels for AM, FM, and TV frequencies are shown in Table 4.

As mentioned earlier, the EPA is now considering three alternative guidance levels structured differently from those used as the basis of the total cost estimates. However, the results of the cost study can be used regardless of the shape of the guidance proposed. The total cost of the guidance can be found by combining the cost of the guidance level applicable for FM, VHF-TV and UHF-TV stations with the cost of the guidance level applicable for AM stations. The range of guidance levels examined in this report should permit combinations to cover whatever shape guidance is finally proposed.

The standard is assumed to apply anywhere on the ground to which the public would normally have access. The public has access to broadcast studios, which are often located very near the transmitting tower.

COMPLIANCE MEASURES RESEARCH

An extensive effort was made to identify technical means for RF sources to comply with various guidance standard levels. The advice of consultants, the broadcast industry, and equipment manufacturers was sought in an attempt to identify all practical solutions. New concepts for compliance measures were identified and subjected to mathematical modeling to test their efficacy. Some of these ideas have proved effective and some have not. A discussion of all of the compliance measures and the group that was selected as practical is given later in this report.

MODEL OF STATION SELECTION OF COMPLIANCE MEASURES

An estimate of the costs of a guidance requires some idea of the choice of compliance measures broadcast sources will make in response to an RF standard. Stations differ in the markets they operate in, their financial condition, the technical aspects of

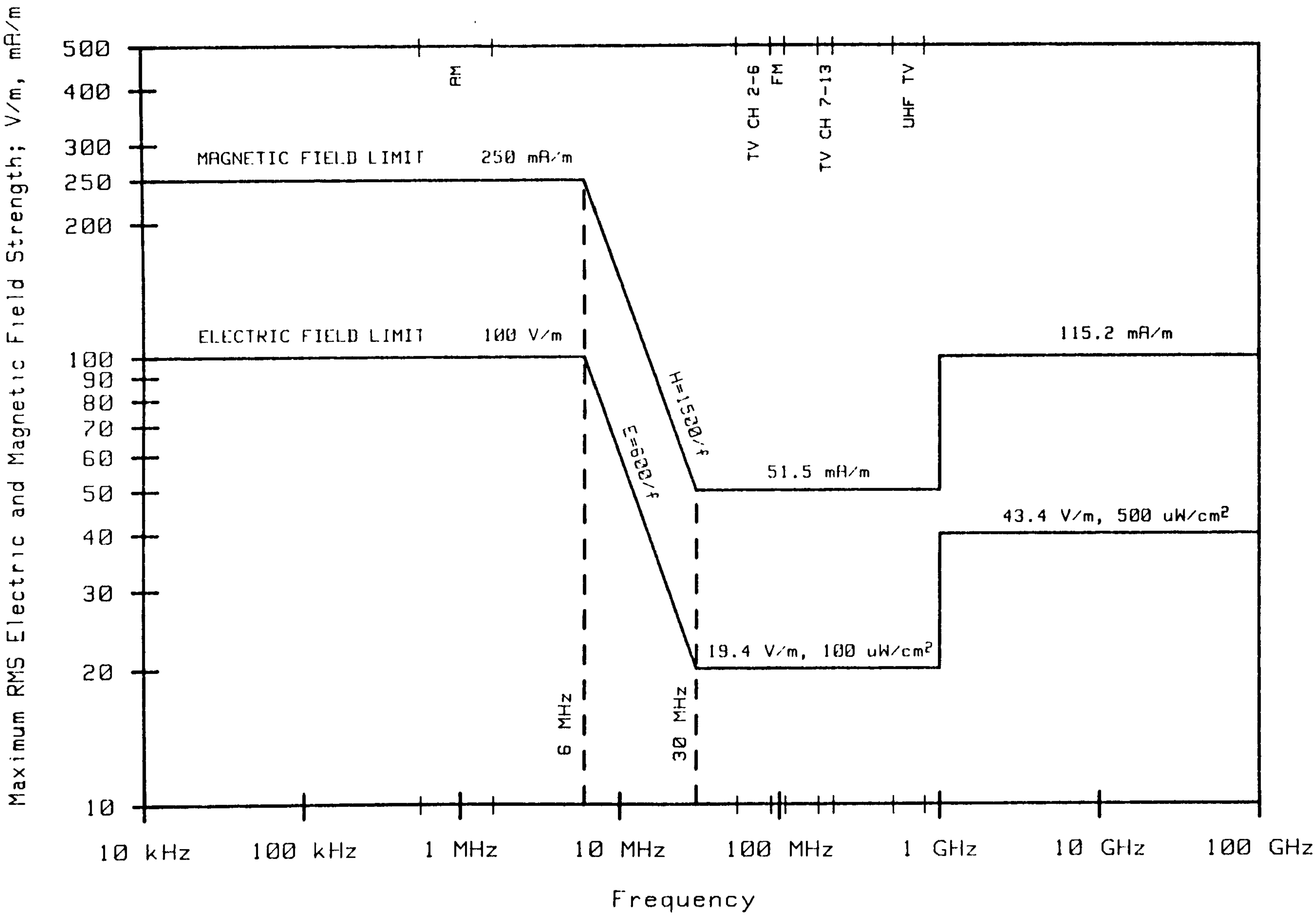


Figure 16. Limiting values of magnetic and electric field strength for a typical guidance for AM, FM, VHF-TV and UHF-TV.

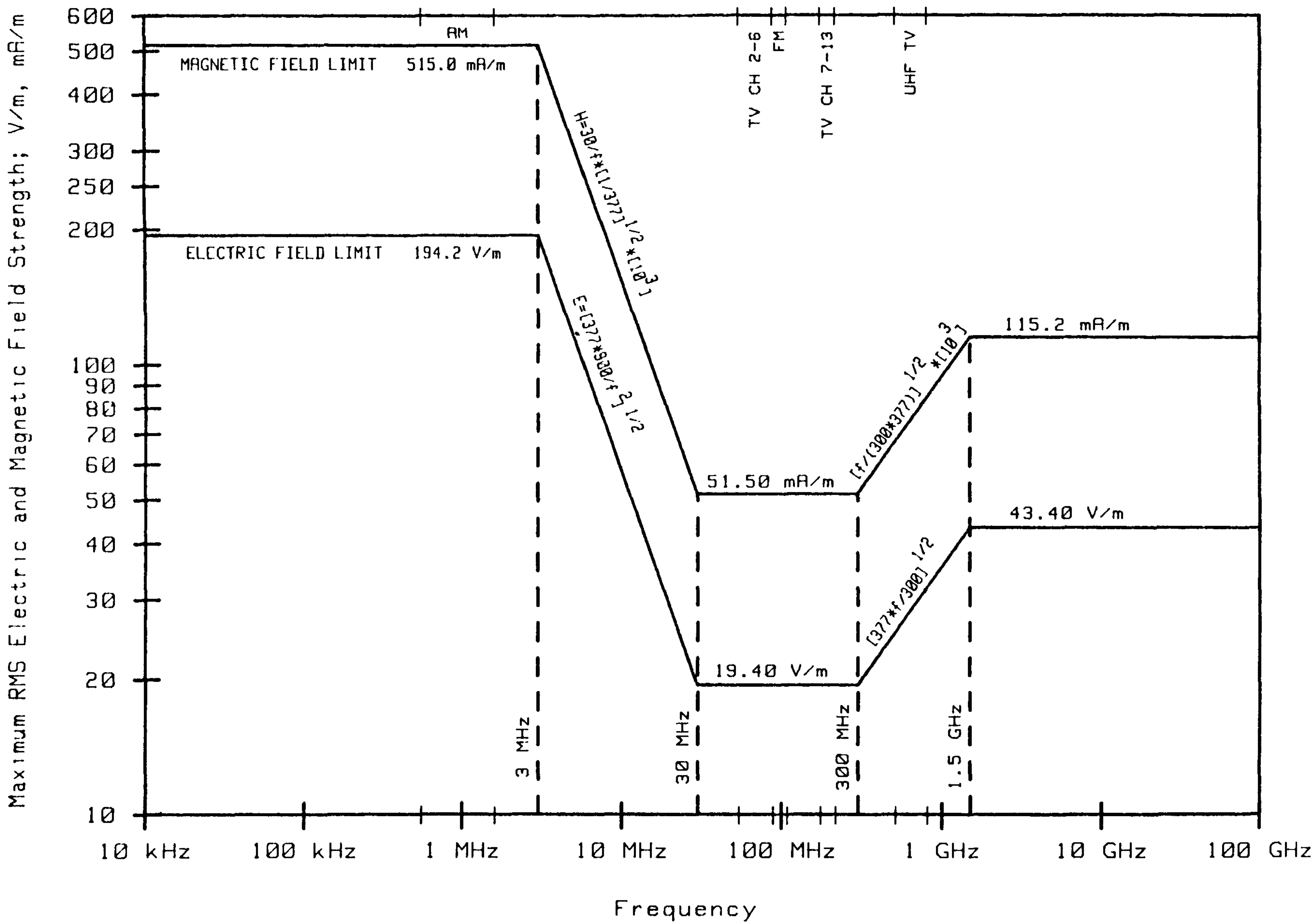


Figure 17. Limiting values of magnetic and electric field strength for another typical guidance for AM, FM, VHF-TV and UHF-TV.

Table 4. Limiting values of the 18 guidance levels for AM, FM, and TV frequencies.[48]

Guidance level	Limiting field strength at AM frequencies V/m	Limiting power densities at FM and TV frequencies μW/cm²
1	10.0	1
2	31.6	10
3	44.7	20
4	70.8	50
5	86.6	75
6	100.0	100
7	141.3	200
8	173.2	300
9	200.0	400
10	223.9	500
11	244.9	600
12	264.6	700
13	281.8	800
14	300.0	900
15	316.2	1,000
16	446.7	2,000
17	708.0	5,000
18	1,000.0	10,000

their broadcast systems and out-of-compliance situation, equipment changes contemplated for other reasons that would minimize the real cost of compliance[a] and the quality and cost of equipment they can afford. Broadcast equipment varies greatly in cost, and since all but one of the compliance measures involve installation of new equipment, cost will be a primary selection criterion.

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[a] A survey of selected FM radio broadcast stations to determine typical equipment rollover schedules was conducted of a large sample of the FM radio stations.[4] The results were not available in time to be taken into consideration in the cost study, but generally, approximately 20% of stations anticipate replacing their antennas within three years, another 10%, within ten years and the remaining 30% do not expect to replace antennas.

Ultimately, each station is assumed to require an engineering study to determine its compliance with the RF guidance, should it be implemented.[a] There are a variety of technical solutions and the choice of the most suited for a particular station will be a function of the factors mentioned above. It was not possible to design a detailed engineering solution for each station that might exceed a particular standard; therefore, the cost models were built on assumptions of compliance measure choice based on the collective professional judgment of the researchers, EPA, broadcasters, and engineering consultants. Generally it is assumed that stations will select the least expensive solution that will achieve compliance.

ENVIRONMENTAL PROTECTION AGENCY COMPLIANCE MEASURES EFFECT MODELS

Individual stations or groups of stations whose RF is estimated to exceed one of the 18 alternative guidance levels studied are assigned the least costly compliance measure, selected in the EPA compliance model from the final list of increasingly complex, effective and costly measures that will effect compliance. Every station was estimated to achieve compliance at every standard level studied using one of the compliance measures. The output of this modeling provides the engineering basis for estimating the costs of compliance.

SOCIETY-AT-LARGE COST ESTIMATION MODELS

The input to the cost models is generated by the compliance measures effects propagation models and cost data developed as part of the compliance measures research. Normally, in a cost benefit analysis, extensive discussion is given to the choice of discount rate used to calculate the present value of a stream of future costs or benefits. It is assumed for the social cost analysis, however, that the costs for compliance with an RF guidance would occur during the year in which compliance is mandated for a station. This assumption is used because the purchase and installation of equipment necessitated by the guidance can easily be accomplished in one year, and, although firms may elect to finance the purchase of the equipment, the terms of payment and cost of borrowing are not

[a] This may not be necessary for all stations. The EPA is developing criteria that will permit stations to conduct preliminary evaluations of the need for a more detailed survey. The conservative assumption used in this analysis somewhat overstates the cost of compliance, particularly at the higher, less stringent, guidance levels.

considered in social cost accounting. Thus, there is no stream of costs. A minor exception is a portion of the cost for one FM radio compliance measure that represents the annual expense of leasing space on another broadcaster's tower. This is a continuing cost that only amounts to one to two percent of the social cost; even though the discount rate used for this fractional component, therefore, has virtually no impact on the aggregate cost, the OMB-suggested rate of 10% was used. It is assumed that stations will comply with the guidance in five equal groups or cohorts over a five year period, one cohort complying in each of five successive years. Because it is assumed that each station faces a once-only cost, the "cash flow" social cost of compliance associated with each cohort complying in a particular year is a one-year undiscounted expenditure. But to calculate the present value to society of the cost of the guidance for all five cohorts with associated expenditures over a five-year period requires discounting the second through the fifth cohort expenditures back to equivalence with the first. Costs to society estimated by the model are presented in terms of gross total compliance cost, including the cost of a survey for all stations and the cost of compliance measures for stations requiring mitigation, annual "cash flow" (undiscounted) cost and total present (discounted) value. The analyses were performed for 18 alternative guidance levels at three cost levels.

INDUSTRY COST ESTIMATION MODELS

Inputs to the industry cost models include compliance measures effects model results, compliance cost data, and income tax variables. The cost to industry analysis differs from the social cost analysis in several ways. The industry cost analysis considers the net-of-taxes cash flow cost of compliance with the guidance. Interest, the cost of financing capital equipment purchases, is included as an expense. But interest, depreciation, expenses, and the investment tax credit reduce tax liability. The cost of compliance is thus shared between industry and the government in the form of tax credits and deductions from taxable income. It is assumed for the industry cost analysis that stations comply in five equal annual cohorts just as in the social cost analysis. However, it is also assumed for the industry analysis that stations incur expenses in the first year and over the subsequent five years of capital amortization. Therefore, the entire industry cost stream is spread over 10 years as each succeeding cohort initiates compliance, followed by five years' amoritization (refer to Appendix Tables D-2, E-2, or F-2 in Volume 2). The industry present value of the cost of compliance is calculated by discounting the entire 10 year cost stream. Costs to industry estimated by the model are presented in terms of projected actual and average annual cash flow costs and present value. The output values are given for 18 guidance levels at three cost levels.

AVERAGE FIRM COST ESTIMATION MODELS

Input to the models of the three broadcast industry segments include compliance measures effects models results, compliance cost data, income tax variables, and income data on the broadcast industry. A more detailed examination of private sector effects of the guidance was made by analyzing the costs in terms of the average AM, FM and TV broadcast station. Models were developed that project pro forma income statements for the average profitable and the average unprofitable FM, AM and TV broadcast stations. It is assumed for the average firm analysis that the individual station faces first-year costs and capital amortization expenses over the next five years. The present value cost for the average firm is calculated by discounting the first year and five subsequent years. The present value cost for the average firm in each of the five cohorts is calculated separately; an average present value cost is derived by calculating the mean of the present value for a firm in each of the five cohorts. Estimates are made of gross and net-after-tax projected and average annual cash flow cost and the effect on taxable income and present value of the net cost of compliance. An analysis is also presented of the maximum and average annual percent reduction in profit (or increase in loss) of the net-after-tax cost of compliance for the average FM, AM and TV broadcast firm. These analyses are presented for 18 guidance levels at three cost-levels as an illustration of the potential effect of a guideline on an individual firm.

SUMMATION COST MODELS

Results of the previous model analyses are used to estimate aggregate social and industry costs of the guidance, the effect of compliance on the average broadcast station, and the total number of broadcast stations requiring a compliance measure at any given guidance level. The summation analyses are given for 18 guidance levels at three costs levels.

MEASURES TO COMPLY WITH RADIOFREQUENCY RADIATION GUIDELINES

During the course of this study much thought has been given to identifying ways in which broadcasters could comply with an RF guideline, if it becomes necessary. Several meetings were held with a number of consultants, equipment manufacturers, and station engineers to identify as many solutions as possible. Two computer design studies were funded as part of this study, the purposes of which were to analyze the efficacy of a variety of bay spacings and groupings in reducing downward radiation.

This research indicates that practical and effective measures to mitigate unwanted levels of RF to comply with a guidance are limited to variations of three actions: (1) exclude or warn the public of areas exposed to RF over the standard, (2) use existing antenna models or design new ones that produce less unwanted downward grating, or side-lobe, radiation, or (3) raise the antenna to reduce the RF energy at ground level. All three compliance measure approaches are applicable to FM radio; only exclusion of the public is appropriate for AM radio; a combination of antenna design and increasing the height of the antenna can be used for television broadcast systems.

The following discussion describes the major ideas considered for potential compliance measures in terms of technical merit and practical acceptance.

REDUCE EFFECTIVE RADIATED POWER

Power density is proportional to the square of field strength; a station could, technically, reduce its broadcast power and power density. Although few listeners in the major reception area of a station would notice even a 50% reduction in ERP, outlying listeners might. Furthermore, success in broadcasting is commonly thought to consist of five elements: market, signal coverage, programming, advertising rates, and promotion. Therefore, station managers and sales/marketing people would perceive such a reduction as a significant loss from a sales viewpoint.

Even if a given station could cover the area of license with grade A reception with lower ERP, its signal cannot be weaker than competing stations without affecting comparative reception and, thus, listener reaction, ratings, and advertising rates. A change in ERP, especially a significant one, can directly affect coverage, and indirectly, market and advertising rates. The other mitigation measures merely affect operating or capital budgets for a short period, but a reduction in ERP may affect revenues. Therefore, broadcasters will do anything to avoid reducing ERP.

Furthermore, the FCC requires stations to maintain a specified signal strength over the broadcast coverage area and to maintain the licensed transmission power output to within -10% to +5%, so a significant reduction in ERP is not feasible.

PROHIBIT PUBLIC ACCESS TO AREAS EXPOSED TO FIELD STRENGTHS EXCEEDING THE STANDARD

This approach assumes a station will conduct an instrument survey of the field strength transmitted by its antenna and then erect a barrier to exclude the public from access to areas exposed to power densities above the standard. The FCC could accept this solution as an absolute deterrent to public exposure to RF above the standard.

The configuration of AM transmitter-antenna systems differs from FM and TV systems, whose antennas are electrically insulated from the towers they are hung on. Transmission of energy occurs only through the physical antenna bays; the tower is merely a means of raising the antenna above surrounding obstructions. However, the entire tower is used to generate the signal in AM systems. AM tower-antenna systems are grounded with an extensive series of radial copper lines buried about 6 inches beneath the surface. Refer to Fig. 13 for an illustration of a generalized AM antenna system. AM stations own or lease an area large enough for the ground-wire system. Many of these antenna systems, which are usually located in undeveloped rural or industrial areas of low pedestrian traffic, are completely fenced, often for other reasons, for example to control cattle grazing. For this analysis, it is assumed that AM stations lease or own land sufficient to exclude the public from the area exposed to RF over the standard level at each guidance level.[4] This compliance measure is the only one appropriate for AM radio broadcast stations.

On the basis of the collective judgment of professional consulting engineers and station personnel, assumptions were made about the number of AM stations whose towers are already adequately protected from public access by fencing. Refer to Table 5 for the percentage of stations assumed to be fenced and therefore need no additional fencing.

POST WARNING SIGNS IN AREAS EXPOSED TO EXCESS RF

The cost analysis was performed on the basis of positive compliance measures that assure that the public will not be exposed to RF radiation above the guidance. However, because many FM antennas are located in remote areas and are inaccessible to all but an

Table 5. Percent of AM broadcast antennas assumed to be adequately fenced to meet RF guideline.

Cost level	Percent of stations
High	15%
Medium	33%
Low	50%

occasional passerby, a separate study was performed of the effect on the cost of compliance of permitting such stations to post signs warning of the over-guidance RF radiation.

A study of population proximal to a sample of SFMT FM antennas shows that a significant portion are very remote from population concentrations. Using 1980 census data and a commercially prepared geographical data base matching 1980 census tract, and census enumeration districts (CED), which are geographical units of varying size corresponding to about 400 population, the geographic location of a sample of FM antennas was compared with the location of these geographical units. Table 6 summarizes the distance of the antenna samples from CEDs. The area surrounding the antenna in which no CEDs (no apparent population) are found is calculated from the radial distance from the antenna to the nearest CED.

It was arbitrarily assumed for the special analysis of the posting alternative that the three most restrictive distance categories would serve as an estimate of the percentage of FM stations that might be allowed to post warning signs as a means of compliance with the RF guidance. Thus, for the low-cost special posting analysis it was assumed that, of the FM stations, 22% could use this solution, the medium-cost analysis, 14%, and the high-cost analysis, 9%. However, because there is considerable uncertainty at this stage about the details of implementation, the primary cost analysis assumes posting warning signs will not be permitted; only the special analysis of the posting alternative assumes this inexpensive solution will be permitted and only the difference between the two analyses is reported.

Table 6. Proximity of a sample of single FM antennas mounted on ground-based towers to Census Enumeration Districts (CED).

	Percent of stations whose antennas are no closer than 6 given distances from a CED					
distance (km)	.5	1.0	2.0	3.0	4.0	5.0
distance (mi)	.31	.62	1.24	1.86	2.49	3.1
area (πmi^2)	.30	1.21	4.83	10.87	19.48	30.19
Percent of stations	81.0	60.0	37.0	22.0	14.0	9.0

INSTALL SHIELD ON BUILDING-BASED ANTENNA TOWERS

FM antennas mounted on masts or towers located on building roofs to which the public has access can expose the rooftop to relatively high field strengths. One solution is to place a shield on the tower just under the antenna that would reflect the signal away from the rooftop. However, successful design of this solution requires extensive engineering studies that will vary with the situation. It is assumed that the number of antennas on roofs to which the public has access is so small that they can be ignored in the analysis.[7] AM and TV antenna systems are not mounted on buildings.

INSTALL REFLECTIVE MATERIALS ON ADJACENT BUILDING WINDOWS

Where an FM antenna on a building-based tower beams the signal horizontally to nearby buildings, the signal can be very effectively reduced by installing reflective mylar material designed to reflect light and heat. This solution is not included in the cost analysis because it is assumed that building-based antennas, in general, do not expose the public to excessive field strengths.

CHANGE THE POWER TO GAIN RELATIONSHIP

The ERP of a station is a function of the power transmitted and the signal amplification (gain) of the antenna. FM and TV antennas, which are similar in design, have more gain (greater multiplication of the signal) with more bays and less gain with fewer bays. Low-gain antennas (fewer bays) tend to produce a large, bulbous main radiation lobe pattern that places a higher intensity of RF in the vicinity immediately beneath the antenna than does a high-gain antenna, which produces a more horizontal beam that does not irradiate the immediate vicinity with as intense an energy level. (All of the energy levels discussed here are low by current safety standards; the point being emphasized here is the relative difference between low- and high-gain FM and TV antennas.) One way to reduce near-field power density might be to redesign the antenna to cast more energy farther from the tower where its intensity would be reduced (power density is proportional to the inverse of the square of the distance; therefore, a beam of RF energy that intercepts the ground at a distance from the antenna will result in weaker power density than a similar beam intercepting the ground close to the antenna).

However, low-gain antennas are increasingly used, especially by FM stations because: 1) they are effective in filling poor-reception areas in valleys below the antenna, 2) they reduce multi-path problems, 3) they improve mobile (auto) receiver reception, a growing segment of the market, and 4) they can result in reduced phase distortion in the transmitted signal. Because this concept would probably meet with a fair amount of industry resistance, it was not pursued.

REPLACE EXISTING ANTENNA WITH A MORE EFFICIENT MODEL

Some FM and TV antennas have a more efficient radiating pattern than others. That is, they concentrate more of the total energy in the main beam or lobe and less in side, or grating lobes. Less efficient antennas have larger "losses" from the main beam into grating lobes, which are often responsible for significant RF on the ground in the vicinity of the antenna. If the existing antenna is of an inefficient type, it can be replaced with a more efficient model, significantly reducing the downward radiation.

This solution may not be appropriate in situations where a station has purposely designed an antenna to broadcast a large lobe to fill poor-reception areas in hilly terrain or in other special-application situations. However, in general, this solution is quite workable and has been used as a compliance measure for both FM and TV antennas.

OPTIMIZE INTER-BAY SPACING OF THE ANTENNA ELEMENTS FOR MINIMAL DOWNWARD RADIATION

FM and TV antennas are normally designed with the bays spaced one wavelength apart for signal phasing and gain purposes. However, if the bays are physically spaced between one wavelength and one-half wavelength apart and the phasing and feed system is modified, adjacent bays tend to cancel out downward radiation while still producing main-beam gain. There is some loss of gain in a less-than-full-wavelength-spaced system compared to a full-wavelength-spaced system, but this can be overcome by adding a few more bays.

The optimal inter-bay spacing would probably fall between one-half wavelength and one wavelength. The optimal spacing for each antenna installation depends on a number of factors such as the desired radiation pattern, antenna and tower configuration, transmitter power-antenna gain relationship, and others. In general, the smaller the inter-bay spacing, the greater the number of supplemental bays required to maintain the original gain. Accurate engineering costing would require detailed knowledge of the new antenna spacing, available only with a complete engineering study. However, determining the radiation performance characteristics of FM and TV antennas, though complicated, can be done by two basic methods: measurement and calculation.

Measurement

A full-size test antenna can be placed on an outdoor antenna pattern range and its transmission characteristics measured. The quality of the range is the key to good results. A good antenna pattern range approximates free space, i.e., it produces patterns as if the test antenna were isolated from all of its surroundings (no appreciable reflections from nearby structures or the earth under the antenna). Such ranges are expensive to establish and generally do not exist.

Scale model measurements of an antenna also can provide radiation characteristics but generally require expensive indoor antenna ranges (anechoic chambers).

Calculation

In order to calculate antenna radiation patterns, one must know the amount of current flowing on all metal parts of the antenna and its supporting and nearby structures. For simple antennas (such as dipoles and loops), a method is employed whereby the current shape is assumed. This method is seldom applicable to commercial FM antennas because they are more complicated than dipoles and loops, primarily because they contain support brackets and vertical feed line sections for which these simple assumptions are inadequate.

One of the project consultants used a computer code developed by two researchers at LLNL called Numerical Electromagnetic Code (NEC),[49] which uses the Method of Moments to calculate the currents on an antenna, regardless of the structure's complexity. This technique can be used by an experienced antenna engineer who is thoroughly knowledgeable in the theoretical limitations of the method to construct an accurate numerical model of the antenna. The results of this kind of analysis have been validated for a wide range of antenna types, which encompass FM structures, during the past 10 years.

The assumption was made in this study that all new antennas with bays optimized for minimal downward radiation would use half-wavelength spacing. This assumption somewhat overstates the cost to industry for this compliance measure but introduces some conservatism in the overall results.

Figure 18, plotted by NEC, shows a typical relationship between FM antenna gain and number of elements for bays spaced one wavelength and one-half wavelength apart.

Of the antenna solutions, this is the most expensive because the old antenna must be replaced and a new one assembled and tested at the manufacturing plant. A greater number of elements is required. Further, the tower often must be analyzed for its structural ability to handle the extra load the greater number of elements would entail. Still, the solution is technically feasible and not prohibitively expensive in many cases. It has been used as a compliance measure for FM and TV antennas in this study. When this compliance measure is assumed to be employed, it is always with a new antenna of a more efficient radiating pattern.

CREATE GROUPS OF ELEMENTS

Two computer modeling studies have been conducted to investigate the effectiveness of this concept in reducing downward radiation for FM and TV antennas.[50] Bays were divided into groups with intra-group spacing maintained at one wavelength and

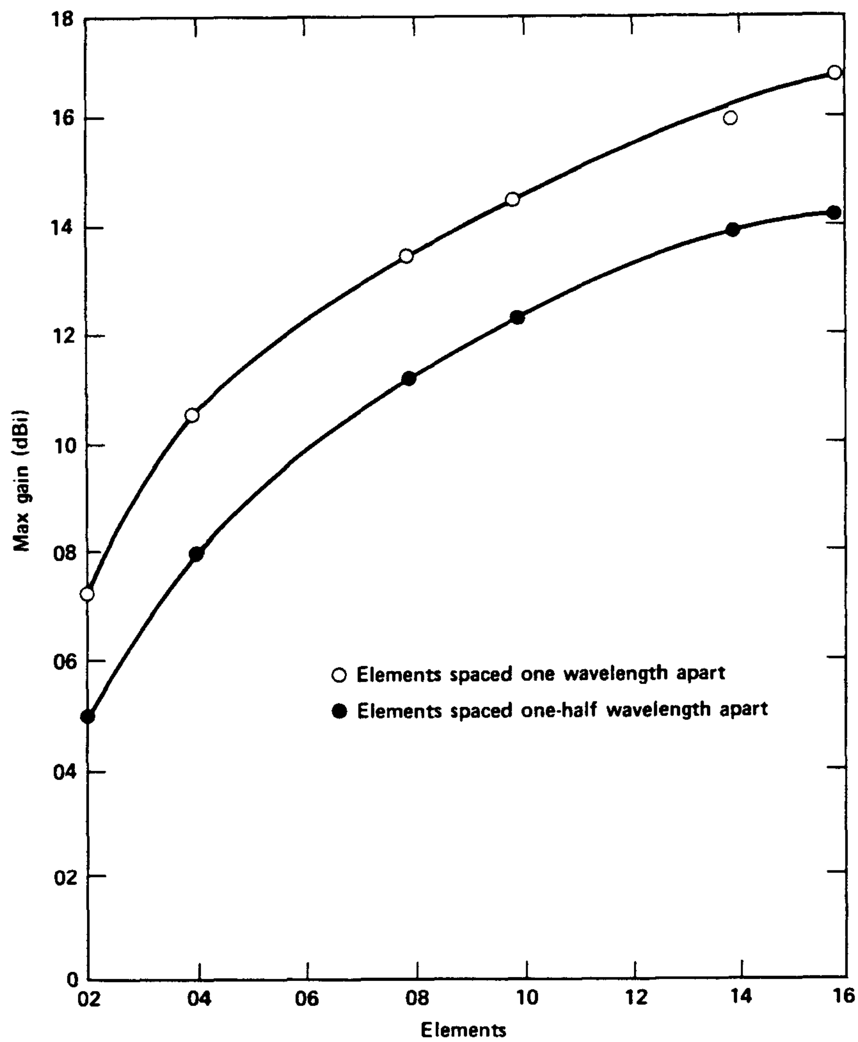

Figure 18. Typical FM antenna gain related to number of elements: a comparison of half-wavelength with full-wavelength spacing.

inter-group spacing either half a wavelength or one-and-one half wavelengths. The studies show that the experimental antenna configurations do not significantly reduce near-field power density. Furthermore, antenna systems with such configurations would have to undergo extensive development and testing by manufacturers. The resulting antenna systems would be more costly than existing ones. Because this measure is apparently minimally effective in reducing near-field power density and will be relatively expensive, it would be impractical, and as a result it was not used in the cost analysis.

RAISE THE ANTENNA

The power density is inversely related to the square of the distance between the source and subject, so raising the antenna to increase its distance from the ground is effective in reducing power density from FM and TV antennas.

However, FM and TV broadcast antennas cannot be mounted on towers built to any arbitrary height a station owner desires. Antennas must conform to a number of FCC regulations, among them a relationship between HAAT and ERP. The relationship differs, depending on the power class of the station, but in general, the taller the antenna in terms of HAAT, the lower the ERP must be to regulate inter-station signal interference. Furthermore, towers generally must conform to FAA regulations, which govern air space obstructions. In addition, there may be height restrictions imposed by local city, county, and township planning bodies. However, in most instances, replacement towers and antennas could be designed to meet FCC, FAA, and local permit requirements. Therefore, it is assumed that towers of the required height will be permitted. Where this is not the case, it is almost certain that some other technical solution can be designed to achieve compliance with the standard, probably at a cost no greater than the estimated cost of a new tower.

Towers are of two types, guyed or self-supporting. In either case, they are built to a given height with a calculated load-bearing capacity. It is not usually possible later to add sections to the top of the tower to raise it because the structure has not been designed to hold the added weight and because the guying has been designed with a given horizontal and vertical geometry that cannot easily be changed. Therefore it is necessary, in virtually every case, to build a new tower to raise an antenna, if lease space cannot be found on an existing taller tower.

Where an antenna can be moved to an existing tower, often a self-supporting TV tower is chosen, because they are so large that the relatively minor added load of an FM

Antenna is usually able to be accommodated. However, very often a detailed structural analysis is necessary to certify the tower's ability to handle the additional load. Often the tower must be structurally reinforced.

The general solution involving raising the antenna has been incorporated into three applications for FM antennas, leasing space on an existing tower, building a taller tower on the existing site, and building a new tower on a new site. TV antennas are assumed to be raised on new towers on the existing tower site. This solution is not appropriate for AM antenna systems, which incorporate the entire tower (usually 1/4 wavelength tall) and an extensive electrical ground system in the antenna system.

SUMMARY OF COMPLIANCE MEASURES FOR FM, AM, AND TV BROADCAST STATIONS

Table 7 shows a summary of the compliance measures used in the analysis of FM, AM, and TV stations. The compliance measures for FM are applied as shown in Table 4, in order of increasing cost. This results, generally, in a minimum cost solution, although there may be occasional non-minimum cost compliance measure selection because, for example, some shorter guyed towers (measures 5,6) are less expensive than some complex one-half wavelength antennas (measure 3). Each TV station was examined individually for the minimum cost compliance measure. For TV antennas, compliance measures 2 and 3 are assumed to be combined to result in an antenna design of reduced downward radiation. Compliance measure 5 is applied to TV with either the existing antenna or a new antenna, depending on cost.

Because FM radio stations are the chief source of public exposure to RF radiation, most of the effort in this study was focused on mitigation measures and costs pertaining to the FM broadcast industry. A number of the compliance measures appropriate for FM antennas may also be appropriate for TV antennas; these include posting warning signs (not used with FM stations except in the special cost study) and building a new tower on a new site. Mitigation for TV antennas includes one tower option, build a taller tower on the existing site. Generally, TV antennas must be placed on the top of a tower; frequently, a TV station or group of stations will build a tower, occupy the top and lease antenna space lower down to FM stations. We assumed that most of the available favorable locations for TV antennas are already occupied because the capital costs and revenue requirements for TV stations required a good antenna location originally to facilitate market coverage. We therefore assumed that the existing tower would be replaced by a taller one in situations where compliance was estimated to be achieved only by raising the TV antenna.

Table 7. Compliance measures assumed available for FM, AM, and TV broadcast stations.

Compliance	FM	AM	TV
1. Post area over-guidance	not allowed[a]	not allowed	not allowed
2. Replace existing antenna with more efficient model with standard 1-wavelength	OK	not applicable	OK for both VHF-TV and UHF-TV antennas
3. Replace existing antenna with more efficient model with bays spaced 1/2-wavelength apart	OK	not applicable	OK only for VHF-TV antennas
4. Lease on taller existing tower	OK	not applicable	not applicable
5. Build new tower on existing site	OK	not applicable	OK
6. Build new tower on new site	OK	not applicable	not applicable
7. Prohibit public access to area over-guidance	not applicable	OK	not applicable

[a] Costs reported assume FM stations will not be allowed to use this inexpensive compliance measure, which does not positively reduce RF levels but warns passersby of excess RF levels. A separate analysis was conducted of the effect on the overall cost of permitting FM stations whose antennas met strictly defined criteria of "remoteness" from population. The savings amounts to as much as 20% for the FM industry and as much as 8% for the entire broadcast industry at guidance level 1. The saving in using posting warning signs declines dramatically at higher guidance levels.

It is also possible that both FM and TV broadcast stations could comply by prohibiting public access to the area exposed to RF radiation that exceeds the guideline. This is the one measure applied to AM stations because there are few alternatives and AM stations generally control access to sufficient land to fence the over-standard area. The owership or leasehold and surrounding land use situation is much less clear for FM and TV stations. The additional factors of possible land purchase or lease costs involved in the fence solution were too varied to include this option for FM and TV antennas.

FM antennas that are raised on taller towers using compliance measures 4,5, or 6 are arbitrarily distributed among those three measures as shown in Table 8. One-third of the stations with antennas co-mounted with one or more other antennas on towers whose antennas are raised using compliance measure 5 or 6 are assumed to relocate with at least one other station, reducing the cost of these measures for the MFMT by one-sixth (1/3 of the MFMT stations x 1/2 the cost).

Many AM radio stations antennas are already protected by fencing for insurance purposes or because they are located in pasture land or as a protection against vandalism. The number of AM stations assumed to have adequately fenced antennas, and thus not requiring a compliance measure, is shown in Table 5. It was assumed that the base of all AM towers are fenced to a distance of 6 ft from the tower and, therefore, any tower estimated to be emitting RF radiation in excess of a given guidance level out to a distance of 6 ft was assumed to be in compliance.

Table 8. Distribution of compliance measures 4, 5, and 6 among single and multiple FM stations requiring antennas mounted on taller towers (percent).

	Fix 4 Lease on another existing tower	Fix 5 Build taller tower on existing site	Fix 6 Build taller tower on new site	Total of three fixes
Low-cost analysis	12.5	75.0	12.5	100%
Medium-cost analysis	25.0	50.0	25.0	100%
High-cost analysis	37.5	25.0	37.5	100%

COMPLIANCE MEASURE COSTS

All stations are assumed for purposes of the cost analysis to require a survey of the electromagnetic environment to determine the need for compliance measures.[a] The survey, probably by a professional consulting engineering or station staff engineer, will be used with a thorough analysis of the station's existing equipment to make decisions about the compliance measure to use. Stations differ so much in equipment configuration, location, market, competition, power requirements, land owned, local soils and meteorological conditions (which influence tower costs), tower accessibility and financial condition that it is not possible to apply a generalized engineering solution to a calculated, rather than a field-measured, problem and accurately cost it. The range of costs from low to high in the following discussion reflects these uncertainities.

The compliance measures applicable to FM stations are detailed in Table 9. The cost of posting warning signs for antennas in remote areas is shown, although this inexpensive measure is not included in the costs reported (see note b, Table 9).

The only positive compliance measure available to AM stations that may be over-standard is fencing to exclude the public from exposure. The cost of fencing is shown with an electromagnetic survey in Table 10.

The compliance measures available to TV stations include replacing the existing antenna with a type that produces reduced downward energy, raising the existing antenna on a taller tower, or building a new tower on a new site with a new antenna. The cost components are shown in Table 11.

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a This may not be necessary for all stations. The EPA is developing criteria that will permit stations to conduct preliminary evaluation of the need for a more detailed survey. The conservative assumption used in this analysis somewhat overstates the cost of compliance, particularly at the higher, less stringent, guidance levels.

Table 9. Costs[a] of compliance measures for FM radio broadcast stations.[51-54]

9.a. Survey of electromagnetic environment around antenna to determine compliance with guideline and need for compliance measure:

	Cost per station		
	Low	Medium	High
Survey	$1,500	$2,000	$2,500

9.b. Compliance measure 1. Post area exposed to over-standard levels of RF.[b]

	Cost per station		
	Low	Medium	High
Percent of stations for which posting assumed to be appropriate	22%	14%	9%
Cost of signs	$2,000	$2,000	$2,000

9.c. Compliance measure 2. Replace existing FM antenna with new model having smaller grating lobe.[c,d]

	Cost per station		
Number of bays	Low[e]	Medium	High[f]
1	$ 1,750	$ 4,690	$ 6,650
2	3,500	8,300	11,500
3	5,300	12,200	16,725
4	7,000	16,200	22,300
5	8,800	21,100	27,700
6	11,400	24,300	32,850
7	13,200	28,300	38,350
8	15,000	32,700	44,500
9	16,700	36,900	50,275
10	18,500	41,000	56,050
11	20,200	44,700	60,960
12	22,000	50,000	65,870
13	26,000	54,200	73,060
14	27,900	59,300	80,250
16	31,700	67,700	91,720

Table 9. (continued)

9.d. The number of half-wavelength spaced antenna elements required to produce the same gain as single-wavelength spaced antenna elements.[g]

Gain dba	Number of antenna elements: One wavelength spacing	Number of antenna elements: One-half wavelength spacing	Ratio of required elements
3.0	1.0	1.0	1.000
6.3	2.0	3.4	1.700
8.5	3.0	5.4	1.800
10.0	4.0	7.5	1.875
10.9	5.0	9.4	1.875
11.7	6.0	11.3	1.875
12.4	7.0	13.1	1.875
12.9	8.0	15.0	1.875
13.5	9.0	16.9[h]	1.875
14.0	10.0	18.8[h]	1.875
14.5	11.0	20.6[h]	1.875
14.9	12.0	22.5[h]	1.875
15.2	13.0	24.4[h]	1.875
15.6	14.0	26.3[h]	1.875
16.2	16.0	30.0[h]	1.875

9.e. Compliance measure 3. Replace existing FM antenna with new antenna whose elements are spaced $\lambda/2$ apart.[c,d,i]

Number of bays	Cost per station: Low[e]	Cost per station: Medium	Cost per station: High[f]
1	$ 1,750	$ 4,690	$ 6,650
2	5,950	14,110	19,550
3	9,540	21,960	30,105
4	13,125	30,375	41,813
5	16,500	39,550	51,950
6	21,375	45,575	61,600
7	24,750	53,075	71,900
8	28,125	61,325	83,450
9	31,325	69,200	94,275
10	34,700	76,875	105,100
11	37,875	83,825	114,300
12	41,250	93,750	123,500
13	48,750	101,625	137,000
14	52,325	111,200	150,475
16	59,450	126,950	171,975

Table 9. (continued)

9.f. Compliance measure 4. Lease space for an FM radio broadcast antenna on another, existing tower.

	Cost per station		
	Low	Medium	High
Equipment[j]	$17,000	$23,000	$27,000
Lease	29,750[k]	59,500[l]	89,250[m]
TOTAL	$46,750	$82,500	$116,250

9.g. Compliance measure 5. Build taller tower on same site as existing tower.[n,o,p]

	Cost per station		
Height (<) of new tower (ft)	Low[q]	Medium	High[r]
50	$14,100	$24,500	$ 32,800
75	15,700	26,800	35,900
100	17,300	29,200	39,000
125	19,600	32,600	43,500
150	21,900	36,000	48,000
175	24,100	39,200	52,300
200	26,500	42,800	57,000
250	30,500	48,700	64,800
300	36,100	56,900	75,700
350	46,700	72,600	96,500
400	54,000	83,400	110,700
500	81,800	105,900	130,000

9.h. Compliance measure 6. Building new tower on new site.[n,o,p]

	Cost per station		
Height (<) of new tower (ft)	Low[n]	Medium	High[o]
100	$60,000	$117,500	$175,000
150	62,500	120,750	179,000
200	65,000	124,500	184,000
250	67,500	128,250	189,000
300	70,000	132,000	194,000
350	75,000	140,000	205,000
400	80,000	151,000	222,000
500	95,000	180,000	265,000

Table 9. (concluded)

Notes for Table 9.

[a]Costs, in 1983 dollars, are for a series of alternative compliance measure options available to an individual FM radio station. The three cost levels reflect variations in equipment configuration, installation conditions, transportation, broadcast conditions and other factors too numerous and station-specific to address for each individual station.

[b] This compliance measure was analyzed only for its effect on the overall cost of compliance. The results reported in this study assume that posting will not be permitted as a positive compliance measure.

[c] Side-mounted, circularly-polarized FM broadcast antennas.

[d] Does not include panel antennas. Prices vary widely depending on the quality of antenna, power rating, how the power is fed to the elements and whether or not the antenna is equipped with deicing or radome all-weather protection excludes low cost "educational" models developed for low power educational stations.

[e] Does not include deicers.

[f] Includes deicers.

[g] Source: plots in Figure 18.

[h] Projections beyond lower curve in Figure 18.

[i] Costs for single-wavelength-spaced antennas in Table 9.c are adjusted by the ratio shown in Table 9.d.

[j] Costs assume half the stations use their existing antennas. Therefore, the costs (low, medium, high) for a 3-bay $\lambda/2$ wave antenna shown in Table 9.e are multiplied by 0.50, to which is added $12,000 for structural analysis and certification. One third of the multiple FM stations are assumed to share an antenna with another station; therefore, in the cost models, the cost shown is multiplied by the factor (1 - (1/3 * 1/2)) for MFM stations.

[k] Assumes annual lease payments of $3,000, discounted over 50 years at 10.0%.

[l] Assumes annual lease payments of $6,000, discounted over 50 years at 10.0%.

[m] Assumes annual lease payments of $9,000, discounted over 50 years at 10.0%.

[n] Tower costs vary widely and depend on site location, size and accessibility, shipping distance and mode, soil load bearing capability, wind and ice loading, height, whether guyed or self-supporting, transmission line used, aviation lighting, local building code requirements and the installation of elevators. Normal transport and installation of tower and antenna are included. Transmitter-associated hardware and some transmission line are excluded.

[o] Assumptions regarding distribution of antennas among compliance measures 4, 5, and 6 (all basically involve relocating the antenna to a taller tower) can be found in Table 8.

[p] In the cost models, it is assumed that half the stations use their existing antennas. The other half are assumed to use a 3-bay $\lambda/2$ wave antenna, the costs for which are multiplied by 0.50 (see Table 9.e) and added to the cost of the tower. One third of the multiple FM stations are assumed to share an antenna and tower with another station; therefore, in the cost models, the cost shown is multiplied by the factor (1 - (1/3 * 1/2)) for MFM stations.

[q] Includes new tower shipped, installed, painted and with power; new transmission line, FCC and FAA application and building permits.

[r] Includes new tower shipped, installed, painted and with power; new transmission line, site improvements, studio-transmitter link, remote control system, FCC performance testing, FCC and FAA application and building permits.

Table 10. Costs of compliance measures for AM radio broadcast stations.

10.a. Survey of electromagnetic environment around tower to determine compliance with guideline and need for compliance measure.[51-54]

	Cost per station		
	Low	Medium	High
Survey	$1,500	$2,000	$2,500

10.b. Compliance measure applicable to AM: fencing to positively keep the public out of areas exposed to over-standard levels of RF.[55]

	Cost per station		
	Low	Medium	High
Fencing per foot	$ 6	$ 9	$ 12
Gate	400	600	800

SOCIETY-AT-LARGE COST MODEL

This model is shown schematically in Fig. 19. The analysis begins with the EPA data base, which provides some of the input to the signal propagation models. The EPA propagation models estimate the signal strength or power density of each broadcast station. These are then analyzed with respect to the 18 alternative guidance levels. The EPA models sort through the appropriate compliance measures (Table 4), applying them in sequence. If, to meet a given guidance level, the first applicable measure is not sufficient to reduce a station's power density, the program selects and tests the next measure, and so on. The result is that each station is estimated to be in compliance with each of the 18 guidance levels by the application of at least one compliance measure.

The social cost model takes these data as input, costs the chosen measure for each station, adds the cost of the electromagentic survey and calculates the component and gross cost, annual "cash flow" (undiscounted) cost and the present (discounted) value of the total cost of compliance for each of the 18 guidance levels analyzed using three cost levels. As is typical with large projects, virtually all the costs occur when compliance is required. Benefits would occur over a long period of time.

To compare current year dollar expenditures with future year expenses and benefits, all dollar values are brought into equivalence by discounting future values to the year of analysis. The fundamental problem with comparing unadjusted dollar values from different years is that current year dollars are more valuable than future dollars. If given a choice, the prudent decision-maker will always prefer to receive a sum of dollars

Table 11. Costs of compliance measures for TV broadcast stations.[51-54,56]

11.a. Survey of electromagnetic environment around tower to determine compliance with guideline and need for compliance measure.[51-54]

	Cost per station		
	Low	Medium	High
Survey	$1,500	$2,000	$2,500

11.b. New Antenna[a]

	Cost per station		
	Low	Medium	High
VHF-TV[b]	$240,000	$480,000	$960,000
UHF-TV	150,000	300,000	600,000

11.c. Tower replacement.[c,d]

	Cost per station		
Height of new tower (ft)	Low	Medium	High
100[e]	$ 57,000	$ 76,000	$ 83,600
200	120,000	160,000	176,000
300	174,000	232,000	255,000
400	262,500	350,000	385,000
500	360,000	480,000	528,000
600[f]	270,000	360,000	396,000
700	307,500	410,000	451,000
800	343,500	450,000	503,800
900	396,750	529,000	581,900
1000	483,750	645,000	709,500
2000	1,875,000	2,500,000	2,750,000

[a] Installed.
[b] Custom design doubles the cost of these antennas over the normal cost. VHF antennas are amenable to design change, UHF's are not.
[c] Tower costs vary widely and depend on site location, size and accessibility, shipping distance and mode, soil load bearing capability, and wind and ice loading, height, whether guyed or self-supporting, transmission line used, aviation lighting, local building code requirements and the installation of elevators. Normal transport and installation of tower and antenna are included. Transmitter, associated hardware, and some transmission line excluded. These costs assume replacement of an existing tower on the same site; no major site preparation except required tower footings is included.
[d] Includes new tower installed, painted and with power; new transmission line, transportation, FCC and FAA application and building permits.
[e] Self-supporting towers.
[f] Guyed towers.

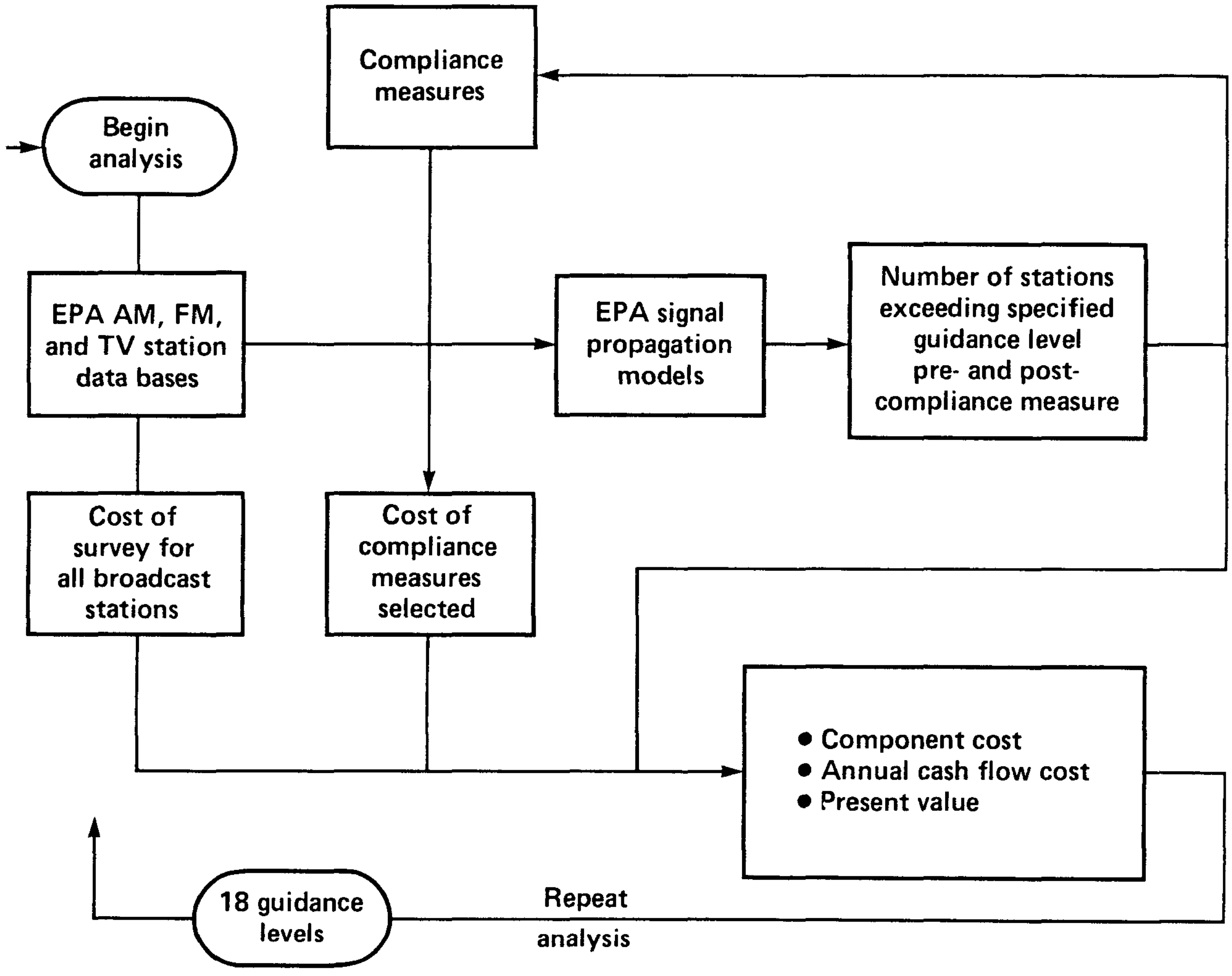


Figure 19. The society-at-large cost model estimates the cost to society of guidance limiting public exposure to RF; the model calculates the component and gross total compliance cost, annual "cash flow" cost and total present value of 18 alternate guidance levels at three cost levels.

immediately rather than the same face value in the future because the dollars received now can be invested or loaned and the value thereby increased. Discounting adjusts the stated current year dollar values so that an equitable comparison can be made exclusive of this consideration.

The basic formula for discounting to obtain the present worth for a uniform annual value is given by:

$$PV = A \quad \frac{(1 + n)^n - 1}{i\,(1 + i)^n}, \tag{2}$$

or for a varying annual value,

$$PV = \sum_{k=1}^{n} A\,(1 + i)^{-k}, \tag{3}$$

where

PV = net present value,

A = annual value,

i = discount rate,

n = total years of analysis, and

k = individual year of analysis.

The fundamentals of time value, equivalence and comparison of money values can be found in a number of texts.[51-64]

In the present cost analysis, only the lease portion of compliance measure 4, applicable to FM radio stations, occurs over a period of time. This cost was discounted over 50 years (equivalent to the life of a tower) at 10.0%, the rate suggested by OMB for this kind of analysis. Inflation can be ignored and costs and benefits valued in constant year dollars if the discount rate takes this into account.[65-66]

The costs are calculated first in terms of the gross component costs for the survey and the compliance measures required. The total of these two divided by five yields the annual "cash flow" cost under the assumption that compliance for the industry would be spread over five years among equal-sized groups or cohorts of stations. This assumption is a way of representing the time that may be involved in surveying for compliance, hiring an engineering firm, determining the appropriate solution, designing the changes, manufacturing the equipment, especially innovative antennas, and installing and certifying the new equipment. Stations will be affected differently by this sequence of steps to compliance, depending on the type of change necessary, complexity of overall broadcast equipment, and availability of engineering services and the necessary equipment.

The total gross cost to society of the guideline limiting public exposure to RF from AM, FM and TV broadcast is given by:

$$TGC = TCS + TCC \quad , \qquad (3)$$

where

TGC = total gross cost of compliance,

TCS = total gross cost of survey for all stations, and

TCC = total cost of compliance measures required.

The annual "cash flow" cost (ACF) of compliance for a given cohort is given by:

$$ACF = TGC/5 \quad , \qquad (4)$$

The present value (PV) of the cost to society-at-large of the guidance is given by:

$$PV = \sum_{k=1}^{5} ACF\,(1.10)^{-(k-1)}, \qquad (5)$$

where

PV = the social cost present value, and

ACF = the annual "cash flow" cost of compliance.

These social costs can be incorporated into a full cost-benefit analysis with the appropriate definition and valuation of benefits. Refer to Appendices A, B, and C for detailed explanations and examples of these calculations.

INDUSTRY COST MODEL

It is of interest to estimate the actual effect of the guidance on the broadcast industry, taking into account the cost of borrowing money for the required capital improvements, the effect on corporate taxes, and the net impact on annual cash flow.

Reference to Fig. 20 will show that the industry cost model is the same as the social cost model through the calculation of the total cost of all compliance measures required for stations exceeding a specified guidance level. From this point, the costs are segregated according to net cash flow and tax impact, in accordance with standard techniques of evaluating projects in a business decision-making context.[67-70] Finally, the net cost of the project is determined from the cash flow and tax benefit estimates.

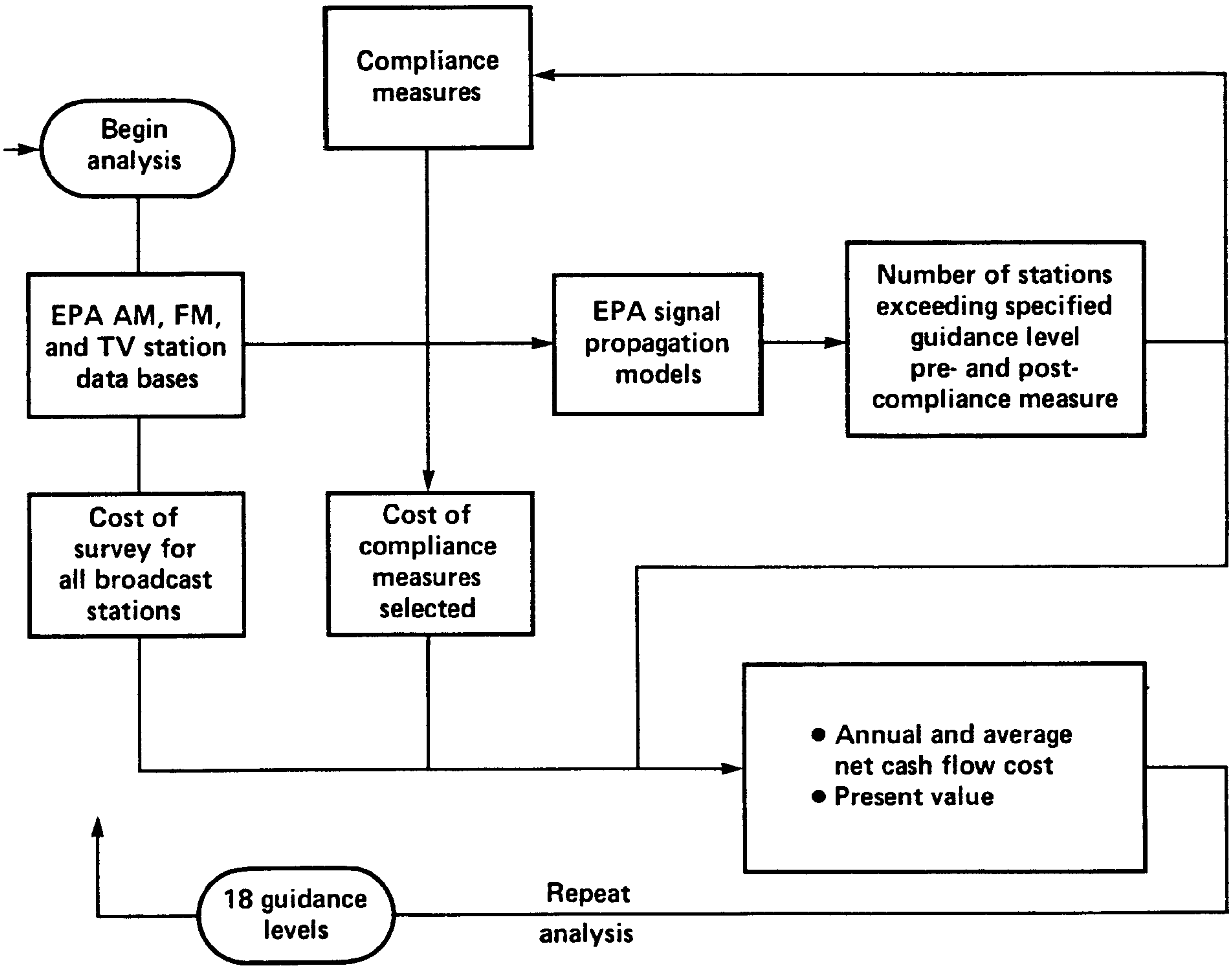


Figure 20. The industry cost model estimates the cost to the broadcast industry of guidance limiting public exposure to RF radiation; the model calculates the annual and average net cash flow and total present value of the cost of compliance of 18 alternative guidance levels at three cost levels.

The present value analysis and the cost of capital are both computed using 10% as the rate, as directed by the EPA. Interest increases the gross expense of the compliance measure but is deductible from gross income and has an effect on the taxes owed.

Tangible property is segregated from intangible expenses because they are treated differently for tax purposes. Tangible property is subject to depreciation and investment tax credit; intangible costs are subtracted from pre-tax profit ("expensed"), generally in the year of occurrence. In this analysis, the lease portion of compliance measure 4 for FM stations and the survey are considered intangible costs and are expensed. For each cohort of stations, the gross annual cash flow cost of compliance with an RF standard consists of:

$$GCF(k) = TCS(k) + DP(k) + LSE(k) + AM(k) + IN(k)\ , \qquad (6)$$

where

GCF = gross cash flow cost,
LSE = lease costs,
DP = down payment,
AM = annual loan amortization payments,
IN = interest on loan,
TCS = total cost of a survey, and
k = year of cost.

The reduction in tax or tax shelter, is given by

$$TS(k) = TR \cdot EX(k) + TR \cdot DPN(k) + TR \cdot IN(k) + ITC(k)\ , \qquad (7)$$

where

TS = tax shelter,
TR = the marginal tax rate applicable to corporate income above $100,000, 0.46,
EX = expensed costs (TCS, LSE),
DPN = depreciation of tangible assets,
I = interest,
ITC = investment tax credit (assumed to be 10%), and
k = year of analysis.

The net annual cash flow cost of compliance for the industry is determined by the following:

$$NCF(k) = GCF(k) - TS(k)\,, \tag{8}$$

where

NCF = net cash flow cost of compliance,
GCF = gross cash flow cost,
TS = tax shelter, and
k = year of analysis.

The NCF for the five cohorts is calculated by dividing the total cash flow cost for the industry by 5:

$$CNCF(k) = NCF(k)/5\,, \tag{9}$$

where

CNCF(k) = the cohort net cash flow cost in year k.

The net cash flow cost of compliance for each of the five cohorts of stations is spread out over six years with each succeeding cohort beginning its six-year expense one year after the preceeding one. Thus, total industry costs are spread over 10 years (5 cohorts of stations, each with expenditures over 6 years). The guidance for each cohort is assumed to be implemented in year zero, during which the electromagnetic survey is conducted, the equipment ordered, down payment (25%) made and investment tax credit taken. During the subsequent five years, the loan is amortized (equal annual principal reductions in accordance with typical commercial line of credit terms), interest paid (annually) and deducted, and depreciation is taken in accordance with the federal tax code accelerated capital recovery system,[71] in contrast to the social cost analysis, which assumes each cohort incurs its costs in one year. The CNCFs are staggered in relation to the following cohort's CNCFs. Therefore, their sum in years k=1 is CNCF (k=1) for the first cohort; the sum of the second year is CNCF (k=2) for cohort 1 plus CNCF (k=1) for cohort 2 and so on. The yearly sums are denoted TNCF(k).

An average NCF is derived as follows:

$$ANCF = \sum_{k=1}^{10} TNCF(k)/10\,, \tag{10}$$

where

ANCF = average annual net cash flow cost.

The industry present value is calculated by discounting the entire ten-year cost stream at 10%, as directed by the EPA, as follows:

$$PV = \sum_{k=1}^{10} TNCF(k)/(1.10)^{(k-1)} . \qquad (11)$$

Refer to Appendices A, B, and C for detailed explanations and examples of these calculations.

AVERAGE FIRM COST MODEL

A more specific analysis was conducted to estimate the effects of the guideline on the average AM, FM, or TV broadcast firm. The individual firm cost model is shown in Fig. 21. It is identical to the social and industry cost models through the calculation of the total cost of all compliance measures required for stations exceeding the specified power density level. From these total industry-wide costs, the average cost for an individual AM, FM, or TV broadcast firm is calculated. The average pre-tax operating profit for profitable AM, FM, and TV broadcast firms[72] was used to create a pro forma profit and loss statement for an average firm in each of the three sectors of the broadcast industry. The additional expenses of compliance are subtracted from gross income; net income is then a function of the tax credit and depreciation, which is substituted for amortization for tax purposes. The analysis assumes that operating profit remains stable throughout the period of analysis, a year "zero" during which the guidance is implemented and five years of loan payments. The impact of compliance on net (after tax) income in years zero to 5 is compared with the assumed net income prior to implementation of the guideline. The financial and ownership structure and tax situation of individual firms are not known; therefore it was assumed that the profit calculated is taxed according to the current corporate tax rate schedule.[73] The costs of compliance for each of the three segments of the industry are averaged over the number of stations requiring a compliance measure at each of the 18 guidance levels analyzed to provide average costs for this analysis.

The effect of compliance with the RF guidance on the average AM, FM, or TV station net profit is estimated in a series of calculations beginning with the gross pre-tax cash flow cost, as follows:

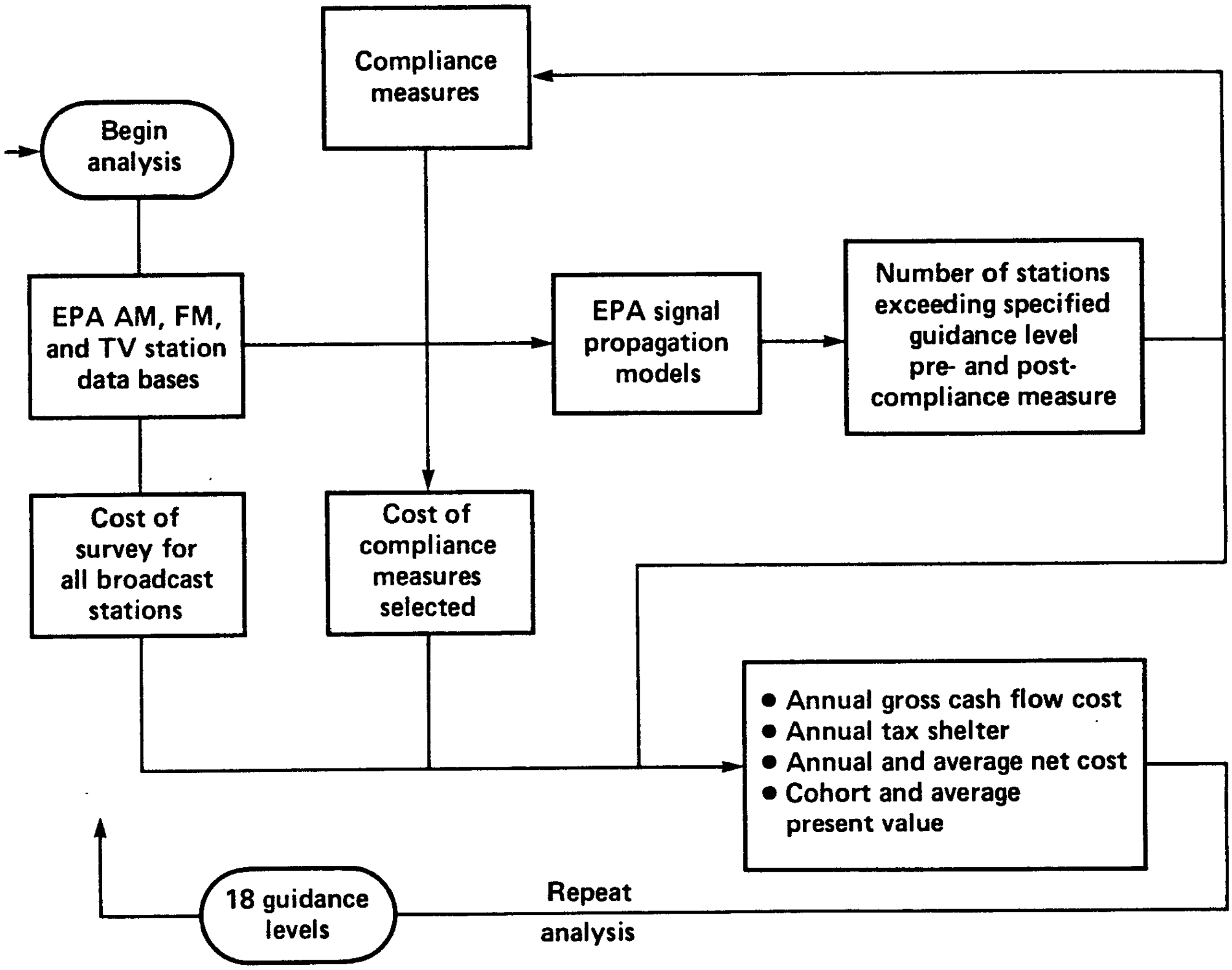


Figure 21. The average broadcast firm model estimates the cost to the average station of a guideline limiting public exposure to RF radiation; the model takes into account the tax effects and calculates the net after tax profit, the annual gross and net cost and the present value of the cost of compliance with 18 alternative guidance levels at three cost levels.

$$AOIA(k) = AOIB(k) - AGCF(k) , \tag{12}$$

where

AOIA = average (AM, FM, or TV) firm pre-tax operating income net of average gross cash flow compliance costs,

AOIB = average (AM, FM, or TV) firm pre-tax operating income as reported in Ref. 72,

AGCF = the average cost of compliance for an individual AM, FM, or TV firm (GCF ÷ total number of [AM, FM, or TV] stations requiring a compliance measure at each power density level), and

k = year of analysis.

Expensed costs, interest (both of which are included in AGCF, above) and depreciation affect the computation of corporate income tax liability as follows:

$$ATOI(k) = AOIA(k) + ADP(k) + AAM(k) - ADPN(k) , \tag{13}$$

where

ATOI = average taxable operating income,

AOIA = average firm pre-tax operating income net of average gross cash flow compliance costs,

ADP = average down payment,

AAM = average loan amortization,

ADPN = average depreciation allowance, and

k = year of analysis.

The gross tax liability is calculated using the corporation tax rate schedule found in Ref. 73.

The net tax liability and net profit are calculated as follows:

$$ANIA(k) = AOIA(k) - ANT(k) , \tag{14}$$

where

ANIA = average net firm after-tax profit,

AOIA = average firm income after compliance and before taxes,

ANT = average net taxes = AGT - AITC,

k = year of analysis, and

where

AGT = average gross tax, and

AITC = average investment tax credit (10% of tangible capital investment), taken in the year of purchase (assumed to be first year of compliance).

The net after tax cash flow cost of compliance for the average broadcast firm is given by:

$$NCC(k) = AGCF(k) - ATSA(k)\,, \tag{15}$$

where

NCC = net cost of compliance,

AGCF = average gross cash flow cost of compliance,

ATSA = average tax savings, (ANTB - ANT(k)),

where

ATSB = average net taxes in the year prior to the guideline,

ANT(k) = average net tax in year k, and

k = year of analysis.

The average net cost of compliance is calculated from the annual net cost as follows:

$$ANCC = \sum_{k=1}^{6} NCC(k)/6\,. \tag{16}$$

The present value cost for the average firm is calculated by discounting the first year and five subsequent years. Each cohort's present value cost is calculated separately. Because there are five cohorts, each realizing costs in succeeding years, the PV of a firm in the last cohort will be substantially less than the PV of a firm in the first cohort. The present value for a firm in each cohort is calculated as follows:

$$PV(c) = \sum_{k=1}^{5} NCC(k)/(1.1)^{k-2+c}, \tag{17}$$

where

PV(c) = the present value of the cost of compliance for the average firm in cohort c,

i = cohort 1, 2, 3, 4, or 5,

k = year of expenditure for the average firm, and

$NCC(k)$ = annual net cost of compliance in year k.

An average present value cost is derived by calculating the mean of the present value for the five cohorts.

$$APV = \sum_{c=1}^{5} PV(c)\ /5 . \qquad (18)$$

A separate analysis was completed of the impact of compliance on the average unprofitable broadcast firm. The results, given the generalized assumptions made for this analysis, are similar to profit-making firms in terms of net cost of compliance. The expenditures for compliance do not, of course, help unprofitable firms improve their income statements.

An analysis was completed of the maximum and average effect of compliance with the guidance on net profit in terms of percent decline in profit (profitable stations) or percent increase in loss (unprofitable stations) as follows:

$$MPE = MNCC/ANPB , \qquad (19)$$

where

MPE = the maximum annual percent effect on net profit or loss,

MNCC = the maximum annual net cost of compliance, and

ANPB = the average net profit or loss in the year prior to compliance.

A similar analysis was completed of the average, as opposed to the maximum effect on profit or loss as follows:

$$APE = ANCC/ANPB , \qquad (20)$$

where

APE = the average annual percent effect on net profit or loss,

ANCC = the average annual net cost of compliance for the average firm, and

ANPB = the average net profit or loss in the year prior to compliance.

A separate program aggregates the AM, FM, and TV industry segment results for the social cost and industry cost analysis to create industry-wide results.

SUMMARY OF ASSUMPTIONS

Throughout the preceeding discussion of method of approach, compliance measures and cost models, a series of assumptions were used. These are assembled below for convenient reference.

GENERAL ASSUMPTIONS

1. AM, FM, and TV stations will select compliance measures in the order of increasing cost used in this analysis.
2. The propagation models, calibrated by a field test program by the EPA, accurately estimate power density propagation; no adjustments need be made for any known biases in these models.
3. For the social cost analysis, all expenses for each cohort of stations are assumed to occur in the year of implementation.
4. For the industry cost and average firm cost analyses, the year of implementation of a guideline is known as "year zero;" expenses are spread out over the following five years. The financial effects of compliance on the average firm are compared with a base year immediately prior to year zero.
5. For all analyses, stations are assumed to comply in five equal annual cohorts.
6. Positive compliance measures are assumed (those that physically prevent public access to RF over the standard). However, the effect of allowing FM stations with remotely located antennas to post warning signs, an inexpensive measure, was analyzed for its effect in reducing the cost of the guideline. For this special analysis, it was assumed that 22%, 14% and 9% of FM stations could post signs for the low, medium and high cost analyses, respectively.
7. All stations are assumed to require a survey of the electromagnetic environment around their towers, whether a compliance measure is needed or not. This assumption may not actually be necessary to implement a guidance because the EPA may be able to devise a self-screening procedure that stations can use to determine on a first-cut basis whether or not a more detailed survey is needed.
8. For the industry and firm cost models:
   a) Capital equipment is purchased at 25% down with 5 annual equal payments, and
   b) Interest is assumed to be 10% as directed by the EPA.
9. A common discount rate of 10% was used in all analyses.

10. For the industry analysis, the tax shelter aspects of the calculations use the top corporate tax rate, 46%.
11. For the individual firm analysis, the corporate tax is calculated according to the federal tax rate schedule.
12. Assumptions for tax shelter used in the individual firm analysis result in identical net costs to profitable and unprofitable stations. It is assumed for this analysis that the losses are passed on to some corporate, partnership or individual tax entity that uses the losses as a deduction.

ASSUMPTIONS FOR FM RADIO STATIONS

1. Stations with tower-mounted antennas were included; building-mounted antennas were not.
2. Both single-mounted and co-mounted antennas on one tower or antenna farms were included.
3. Compliance measures were generally applied in the order of increasing cost.
4. For compliance measures involving replacement of antennas, the old antenna was replaced with one of equivalent ERP.
5. Because the EPA data base contains only 3895 (89%) of the 4374 FM radio stations, it was assumed that the larger group of FM stations contain the same ratio of antenna types, tower heights, ERP, etc. as the group in the data base. Thus, each group of FM stations was increased by 4374 ÷ 3895 = 1.123.
6. On the basis of professional judgment, those FM stations that could not achieve compliance using fixes 2 or 3 were distributed among compliance measures 4, 5, and 6 (Table 15) according to the percentages given in Table 8.
7. It is assumed for compliance measures 4, 5, and 6 that half the stations can use their existing antennas; the cost of a 3-bay, $\lambda/2$ antenna (Table 9.e) was multiplied by 0.5 and added to the cost of a structural analysis for compliance measure 4 ($12,000), and to the cost of a new tower for compliance measures 5 and 6.
8. One third of the stations with antennas co-located on towers with other FM stations are assumed to relocate with another station if compliance measure 4, 5, or 6 is used, reducing the cost of these measures by 1/6 for these stations as a whole (1/3 of stations x 1/2 cost).
9. The EPA-FCC data on antenna height are based on the center of ERP; therefore, for costing purposes, 25' was added to the height of each tower needed for compliance measures 5 and 6; 25' is half the average height of a typical 6-bay FM antenna.

ASSUMPTIONS FOR AM RADIO STATIONS

1. Varying percentages of AM stations were assumed to have existing adequate fencing (see Table 5) reducing the overall cost of compliance accordingly.
2. The area fenced is assumed to be square; the fence contains one 20' gate for vehicular access.

ASSUMPTIONS FOR TV BROADCAST STATIONS

1. It is assumed that TV antennas can be modified in a manner similar to that of FM antennas to reduce downward radiation from grating lobes.

SUMMARY OF RESEARCH RESULTS

The results of the economic study are presented in the following series (at the end of this section) of summary figures (Figs. 22-49) and tables (Tables 12-17); more detailed data are given in Volume II, Appendices D-G. The presentation of the summary results is organized into the following sequence: total (FM, AM, TV) social cost, total industry cost, FM average firm, AM average firm, TV average firm, FM-AM-TV cost distribution, compliance measure component cost analysis, FM compliance measure one cost analysis, and number of stations affected by the guidelines.

What are the costs to the society-at-large of the proposed guideline limiting public exposure to RF from broadcast sources? Figures 22 and 23 at the end of this section give the range (low, medium, and high cost assumptions) of the cost to society-at-large of a guidance limiting public exposure to RF from AM, FM, and TV broadcast sources for 6 of 18 guidance levels analyzed. Figure 22 shows the cost in terms of total present value; Figure 23 shows the annual cash flow cost. The PV of the cost to society varies from a maximum (high cost assumptions) of $866.6 million for guidance level 1 to a minimum (low cost assumptions) of $12.7 million for guidance level 18. The cash flow cost to society varies from $207.8 million to $3.1 million. Data for these figures are identified in Table 12 at the end of this section and also in Table G-1 in the Appendix.

How much will the proposed guidelines cost the broadcast industry as a whole? In contrast to the cost to society, the PV of the cost of the guidelines to the total broadcast industry (Fig. 24) varies from $414.6 million to $6.9 million. The average net after tax CFC of the cost of compliance for the total broadcast industry (Fig. 25) is also less than the equivalent cost to society, varying from $59.1 million to $0.8 million. Data for these figures are identified in Table 13 at the end of this section and also in Table G-2 in the Appendix. The lower costs to industry as contrasted with the costs to society result from the difference in definitions of the two costs. The cost to society-at-large is defined as including all the opportunity costs (costs of using resources for one use and foregoing the opportunity to use them for other uses); the cost to industry is an estimate of the net cost and includes transfer payments not considered in the social cost, such as tax deductions and credits and interest on funds assumed borrowed for the compliance measures.

The next 12 figures show the range of the estimated cost of compliance for the average (FM, Figs. 26-29; AM, Figs. 30-33; TV, Figs. 34-37) broadcast station in terms of average PV, average net CFC, and the maximum and average reduction in net profit resulting from the net CFC cost of compliance; all shown for 6 of 18 guidance levels. The average present value of the cost of compliance for the average broadcast station varies from $40.6 thousand (FM-Fig. 26), $7.9 thousand (AM-Fig. 30), $285.3 thousand (TV-Fig. 34) at guidance level 1 to $4.8 thousand (FM), $1.3 thousand (AM), $0.7 thousand (TV) at guidance level 18. The average CFC is estimated to vary from a maximum of $9.7 thousand (FM-Fig. 27), $1.8 thousand (AM-Fig. 31), $67.8 thousand (TV-Fig. 35) at guidance level 1 to a minimum of $1.1 thousand (FM), $0.3 thousand (AM), $0.1 thousand (TV) at guidance level 18. The estimated reduction in profit associated with the maximum cash flow cost for compliance over six years for the average broadcast station is shown for FM (Fig. 28), AM (Fig. 32), and TV (Fig. 36) and varies from a maximum of 16.4% (FM) at guidance level 1 to 0.10% (TV) at guidance level 18. The reduction in net profit associated with the average cash flow cost for compliance over six years for the average broadcast station is shown for FM (Fig. 29), AM (Fig. 33), and TV (Fig. 37) and varies from a maximum of 10.1% (FM) at guidance level 1 to 0% (TV) at guidance level 18. Data for these figures are identified in Table 14 at the end of this section and in Tables D-3, E-3, F-3, and G-3 in the Appendix.

The net effect of the maximum annual net after tax cash flow cost of compliance on unprofitable broadcast stations is the same in absolute dollar terms as for profitable stations but the percentage effect varies with the guidance level and the cost level. The average unprofitable FM radio station loses 18% more than the average profitable station makes net of taxes,[72] so the same cost of compliance will be a smaller percentage addition to the average losses than reduction in the average profit. The average unprofitable FM station will experience an average increase in net losses varying from about 19% (guidance level 1 - high cost) to about 1% (level 18 - low cost). The average unprofitable AM radio station loses 8% less than the average profitable station makes net of taxes,[72] so the same compliance costs will be a greater percentage of losses than profits. The average unprofitable AM station will have average increased losses ranging from about 3% (guidance level 1 - high cost) to less than 1% (level 18 - low cost). The average unprofitable TV broadcast station loses only 31% as much as the average profitable station makes net of taxes[72] so the same absolute dollar cost of compliance will be several times greater in percentage terms for unprofitable stations than for profitable ones. The average unprofitable TV station will experience increased losses ranging from about 27% (guidance level 1 - high cost) to especially zero (guidance level 18 - low cost).

The general pattern of all costs (and the number of stations requiring a compliance measure at a given guidance level) is clear; the cost of the guidance drops dramatically from guidance level 1 (1 $\mu W/cm^2$ - FM/TV RF units), the most stringent analyzed, to about 4 (20 $\mu W/cm^2$), then falls rapidly to about 9 or 10 (400 $\mu W/cm^2$) and more gradually to guidance level 18 (10,000 $\mu W/cm^2$), the least stringent level analyzed.

How do the three major segments of the broadcast industry compare in the share of the costs of the guideline attributable to them? An analysis of the distribution of costs among the three industry segments was made using the medium level PV of the cost to society; the distribution is shown in Fig. 38 for 6 of the 18 guidance levels. At guidance level 1, the cost of compliance for TV broadcast stations predominates because the compliance measures are more costly for TV than for radio stations. Thereafter, the number of TV stations requiring a compliance measure drops sharply and FM radio stations dominate the total cost until the last guidance levels are reached, when the relatively larger number of AM stations requiring a compliance measure causes the AM sector to predominate. Even though the number of AM radio stations requiring a compliance measure is greater than the number of FM stations beginning with guidance level 2 (Tables 15-17), the compliance measures for FM stations are more complex and costly than those for AM stations, causing the expenses for the FM segment to exceed those for AM up to guidance level 17. Data for this analysis are identified in Table 12, medium-level TNPV cost to society; also see Tables D-1, E-1, F-1, and E-1 in the Appendix.

The total cost of compliance can be grossly segmented into two components, the cost of a survey of the RF environment around the antenna to determine the need for and extent of mitigation measures required and the cost of the compliance measure itself. The distribution of these two cost components is shown for FM (Fig. 39), AM (Fig. 40), and TV (Fig. 41) based on the medium-level component cost to society-at-large. The consistent pattern is that, at lower, more difficult-to-achieve guidance levels, the cost of the compliance measure predominates. However, at less stringent standard levels (guidance level 12, FM; guidance level 4, AM; guidance level 8, TV) the cost of the survey for all stations exceeds the cost of compliance for those stations requiring it. Data plotted in Figs. 39, 40, and 41 are identified in Tables D-1, E-1, F-1, respectively, in the Appendix.

Although the cost analyses were performed assuming some form of positive compliance, the EPA investigators observed in the course of their work that many FM transmitters are located in remote areas often inaccessible to the public. Therefore we tested the effect on costs of assuming that a percentage of FM stations would be permitted to post warning signs around antennas that emit RF above the guideline. The percentage of stations allowed this inexpensive solution was based on criteria for remoteness developed from population statistics using CED data in conjunction with the geographic location of FM antennas. Allowing FM stations, whose antennas are defined as remote, to post warning signs reduces the cost to society of the guidelines for the FM segment of the broadcast industry at guidance level 1 by up to 20% (Fig. 42) and reduces the cost of compliance to the FM broadcast industry by very nearly 20% (Fig. 43). Reductions in cost at less stringent guidance levels display the same decline as overall costs. When the other two segments of the broadcast industry, which are not affected by the inexpensive posting option, are combined with the FM segment, the overall effect is diluted. The overall cost to society of the guideline is reduced by a maximum of 8% at guidance level 2 (Fig. 44); the overall cost of compliance to the broadcast industry is reduced by about 7.5% at guidance level 2 (Fig. 45). The plots in Figs. 44 and 45 show that cost reductions are depressed at guidance level 1, after which they rise and then resume a pattern consistent with the cost-guidance level relationships discussed earlier. The reason these cost reduction curves increase before decreasing relative to guidance level is that the cost of compliance for TV stations, which is not affected by the posting solution, dominates the total cost at guidance level 1 (see Fig. 38). However, beginning with guidance level 2, the cost of compliance for the FM broadcast sector is higher than the cost for the AM and TV sectors combined, so the cost reduction that is applicable to the FM sector has a greater effect on the aggregate cost of compliance at guidance level 2 than at guidance level 1.

How many stations would require measures to comply with a guideline if it were implemented? The number of stations assumed to require some kind of compliance measure other than the survey is shown for FM (Fig. 46), AM (Fig. 47), and TV (Fig. 48). The assumptions for selection of compliance measures and for differences among the three cost levels result in three distinctly different numbers of AM radio stations requiring compliance measures at the low, medium, and high cost estimates, which is reflected in the three plots in Fig. 47. The number of FM and TV broadcast stations that require a compliance measure is constant across all three cost levels (Figs. 46 and 48). The number of AM stations varies with the cost level because assumptions were made about the proportion of stations already fenced at the three cost levels (see Table 5). The percentage distribution of the number of FM, AM, and TV stations requiring a compliance measure is shown in Fig. 49 at 6 of the 18 guidance levels studied. This distribution differs from that shown for costs in Fig. 38 for two reasons. First, though the number of stations actually requiring a compliance measure declines to very small numbers at the less stringent guidance levels, all stations were assumed to require a survey (and the associated cost) at all guidance levels. Further, the cost of compliance for TV broadcast stations is disproportionately costly relative to the number of TV stations requiring a compliance measure. Data for Figs. 46-48 are identified in Tables 15, 16, and 17 at the end of this section and also in Tables D-4, E-4, and F-4 in the Appendix.

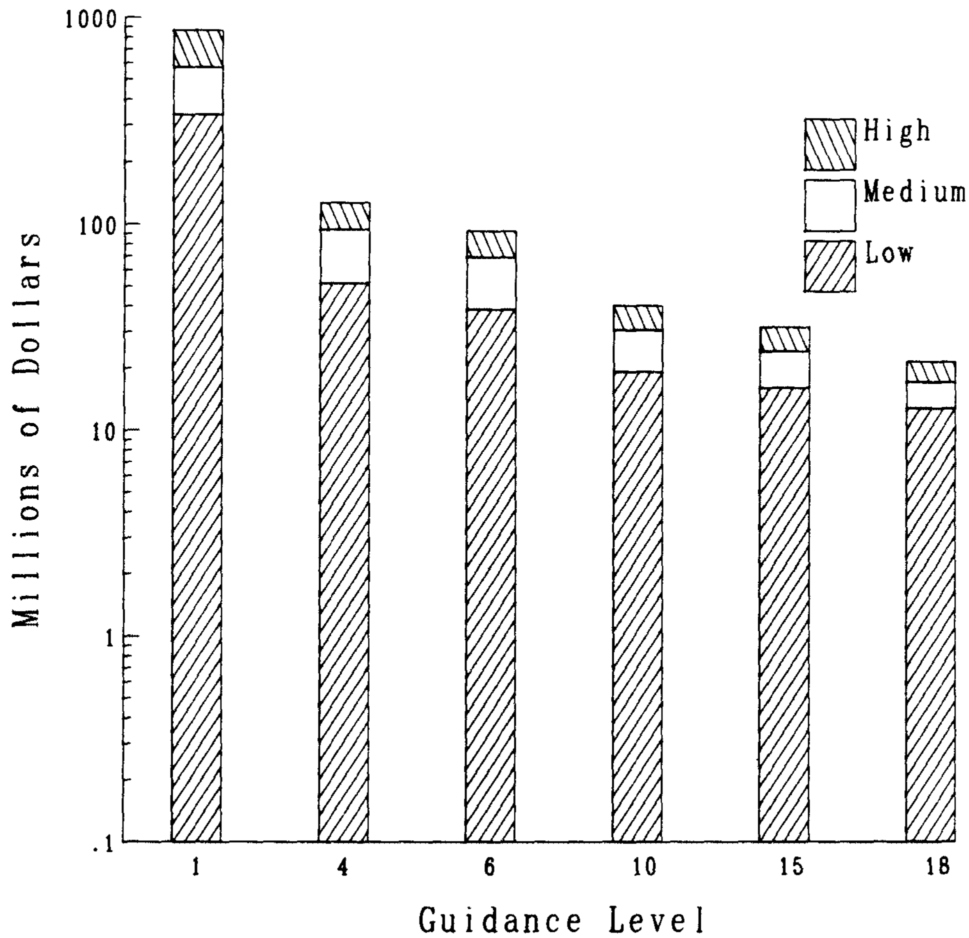


Figure 22. The range of total present value (constant dollar) cost to society-at-large of guidelines limiting public exposure to radiofrequency radiation from AM, FM, and TV broadcast sources is shown for 6 of 18 guidance levels studied.

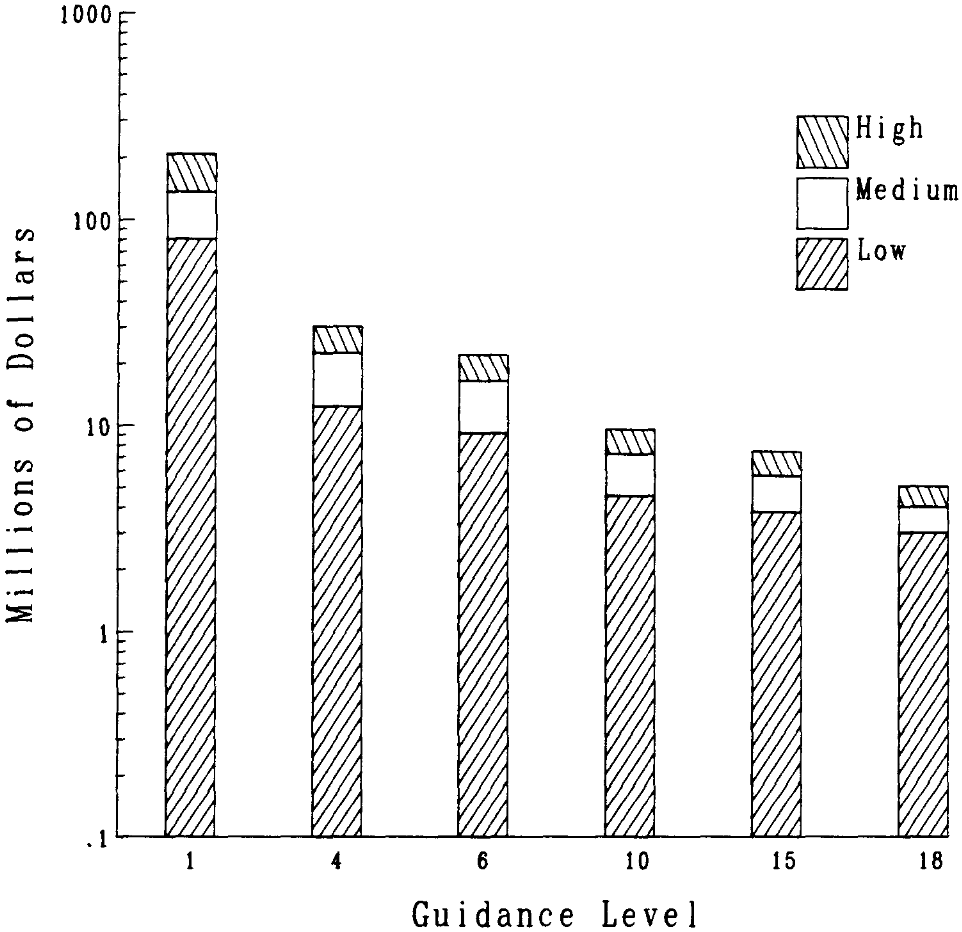


Figure 23. The range of annual cash flow (current year dollar) cost to society-at-large of guidelines limiting public exposure to radiofrequency radiation from AM, FM, and TV broadcast sources is shown for 6 of 18 guidance levels studied.

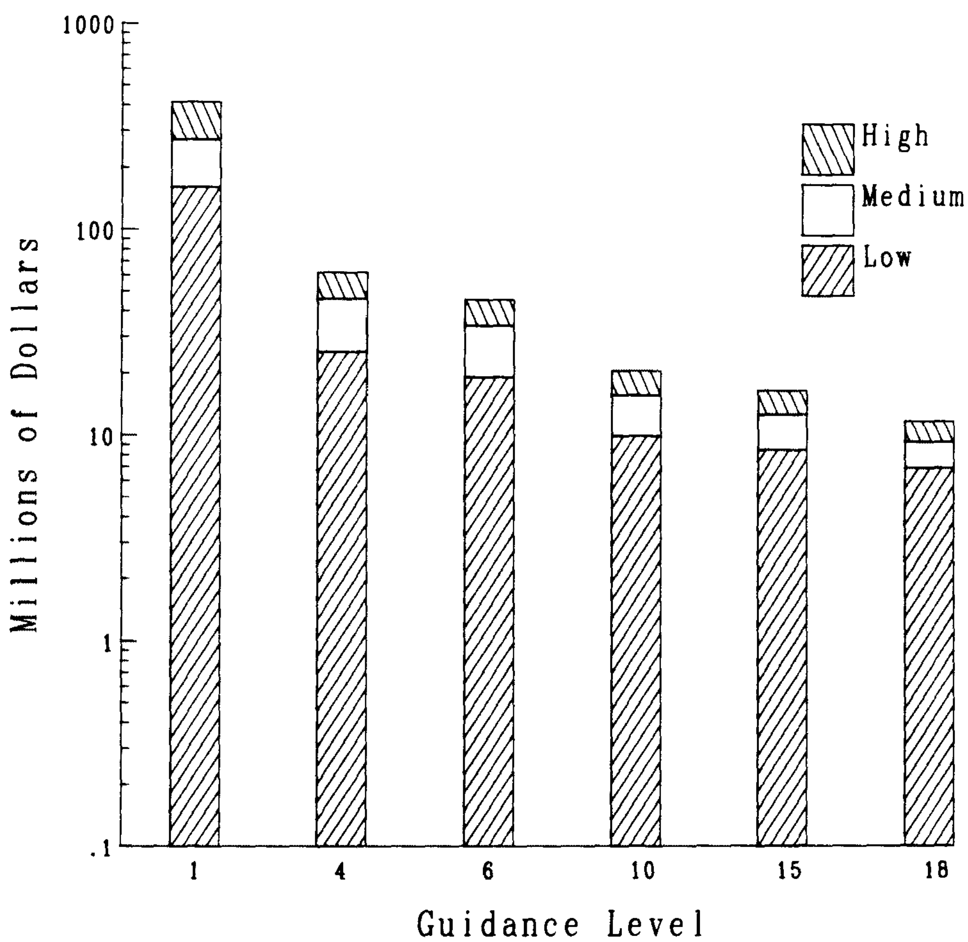


Figure 24. The range of the total present (constant dollar) value of the net after-tax cost to the broadcast industry of guidelines limiting public exposure to radiofrequency radiation from AM, FM, and TV broadcast sources is shown for 6 of 18 guidance levels studied.

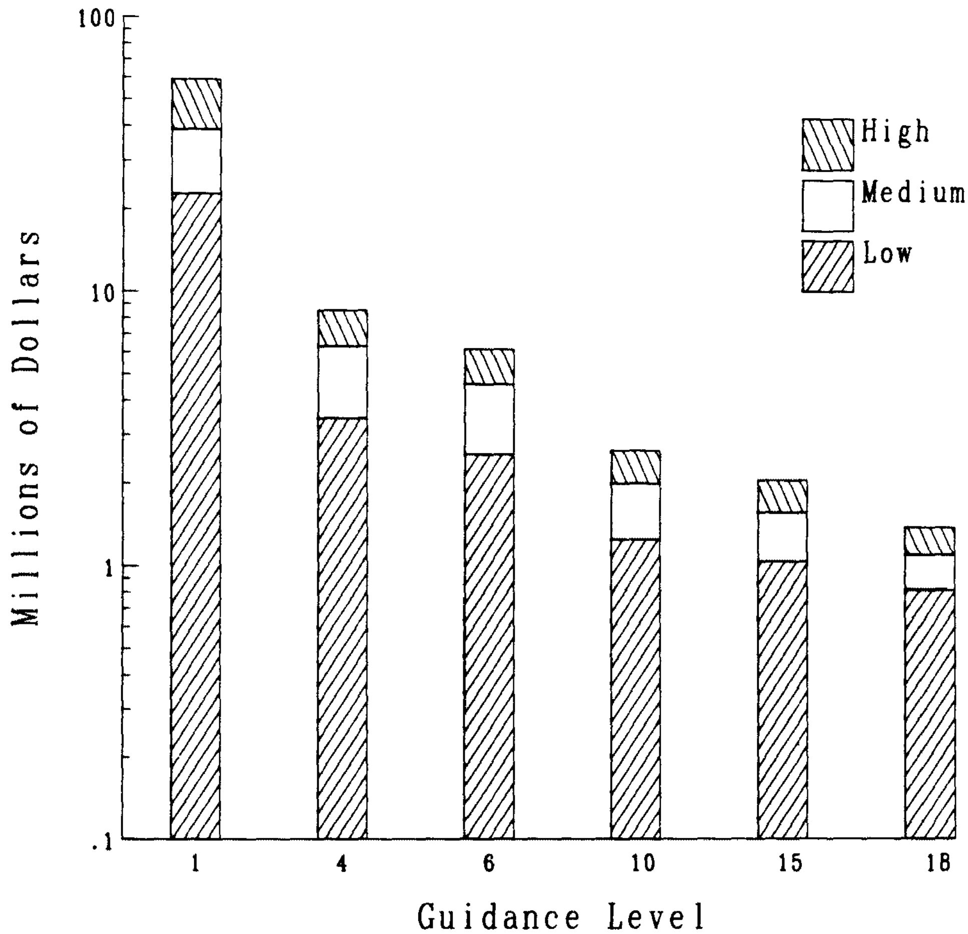


Figure 25. The range of average annual net after tax cash flow (current year dollar) cost to the broadcast industry of guidelines limiting public exposure to radiofrequency radiation from AM, FM, and TV broadcast sources is shown for 6 of 18 guidance levels studied.

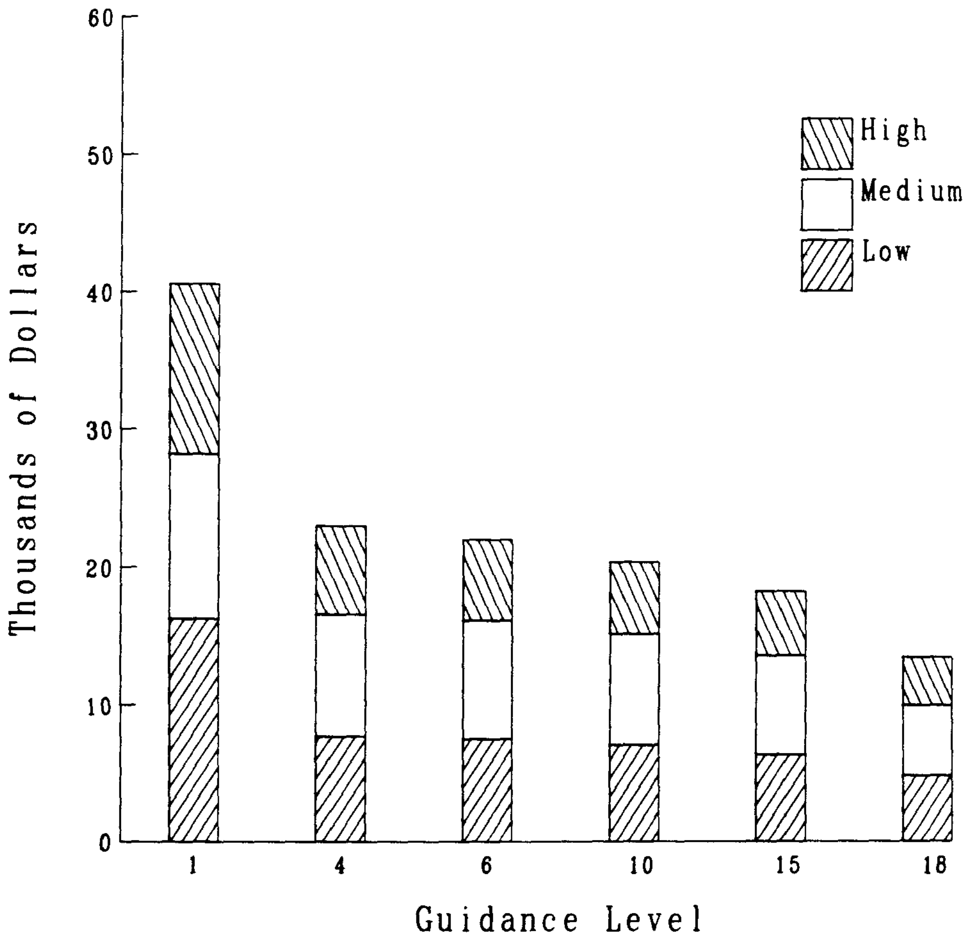


Figure 26. The range of the average (of 5 cohorts) present (constant dollar) value of the net after-tax cost to the average profitable FM radio broadcast station of guidelines limiting public exposure to radiofrequency radiation is shown for 6 of 18 guidance levels studied.

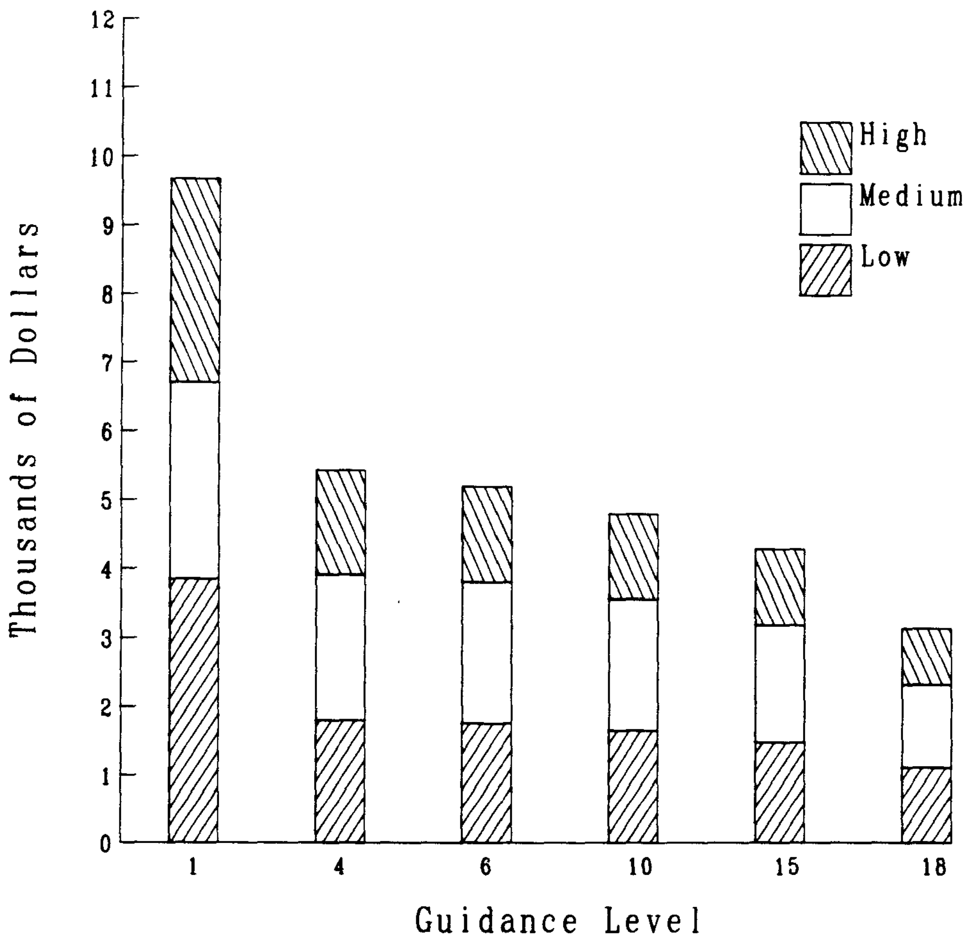


Figure 27. The range of average annual net after-tax cash flow (current year dollar) cost to the average profitable FM radio broadcast station of guidelines limiting public exposure to radio-frequency radiation is shown for 6 of 18 guidance levels studied.

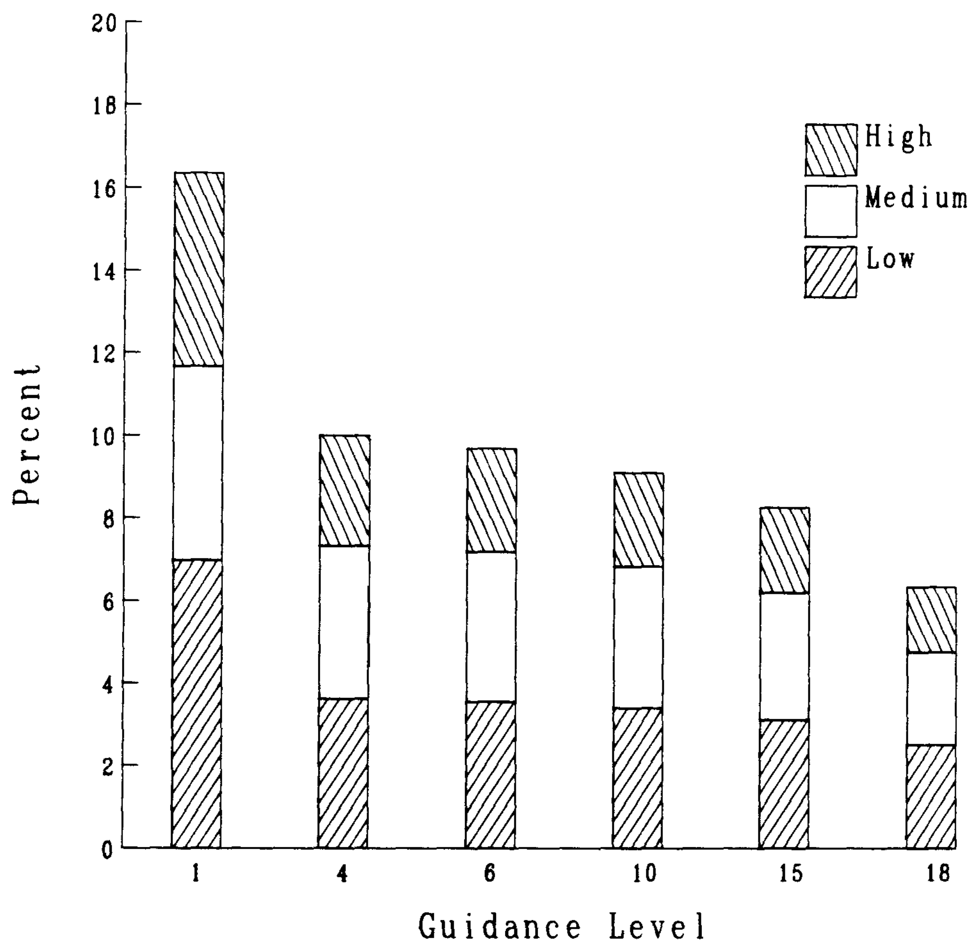


Figure 28. The percentage reduction in the net profit of the average profitable FM radio broadcast station associated with the maximum annual cash flow cost of compliance with guidelines limiting public exposure to radiofrequency radiation is shown for 6 of 18 guidance levels at 3 cost levels.

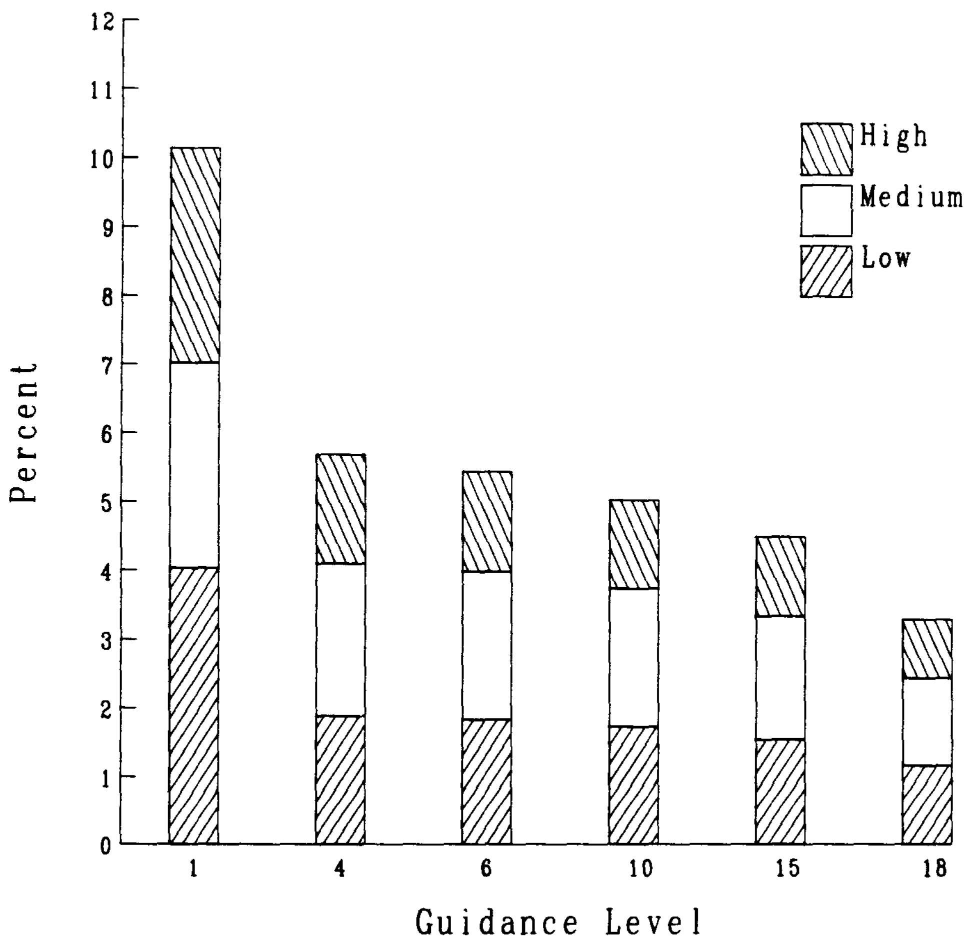


Figure 29. The percentage reduction in the net profit of the average profitable FM radio broadcast station associated with the average annual cash flow cost of compliance with guidelines limiting public exposure to radiofrequency radiation is shown for 6 of 18 guidance levels at 3 cost levels.

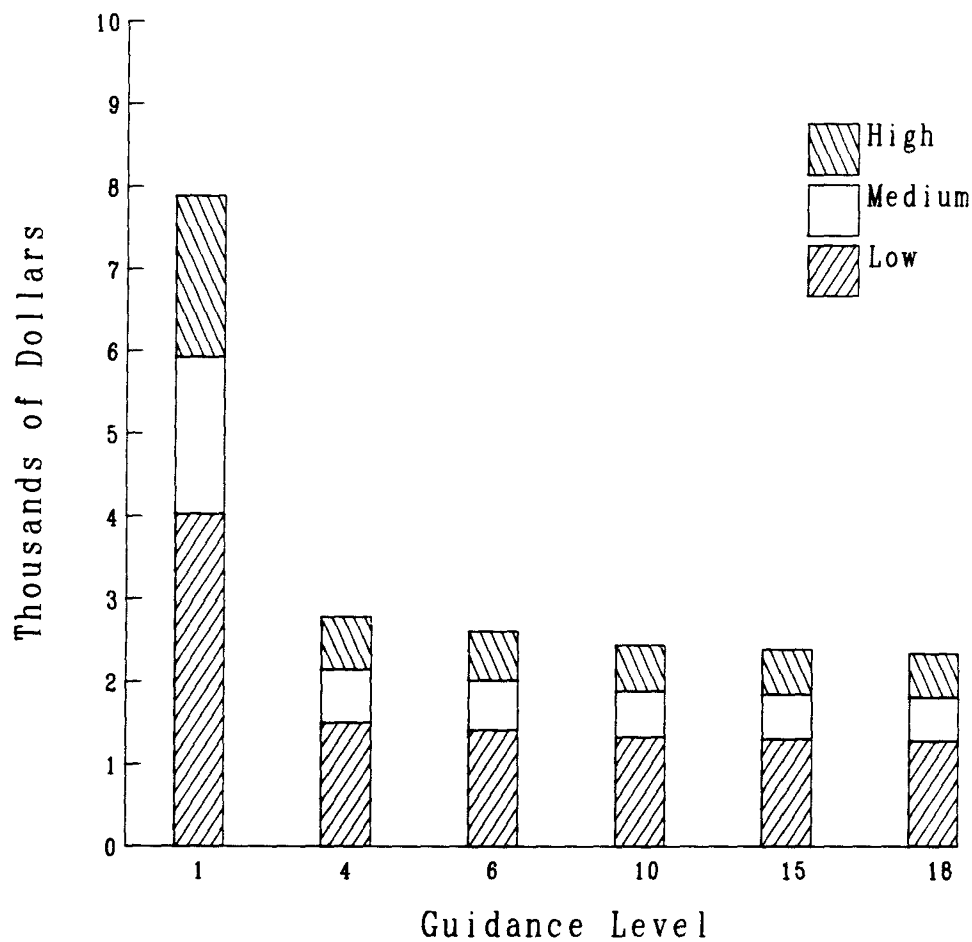


Figure 30. The range of the average (of 5 cohorts) present (constant dollar) value of the net after-tax cost to the average profitable AM radio broadcast station of guidelines limiting public exposure to radiofrequency radiation is shown for 6 of 18 guidance levels studied.

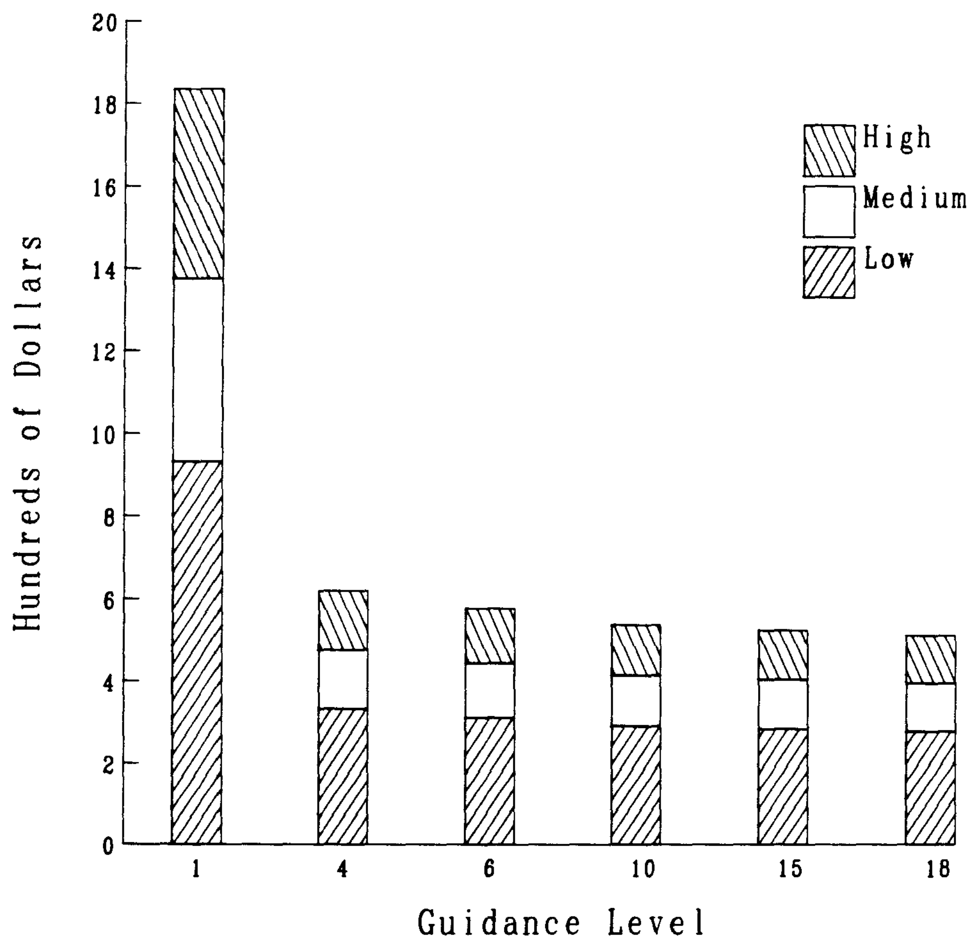


Figure 31. The range of average annual net after-tax cash flow (current year dollar) cost to the average profitable AM radio broadcast station of guidelines limiting public exposure to radio-frequency radiation is shown for 6 of 18 guidance levels studied.

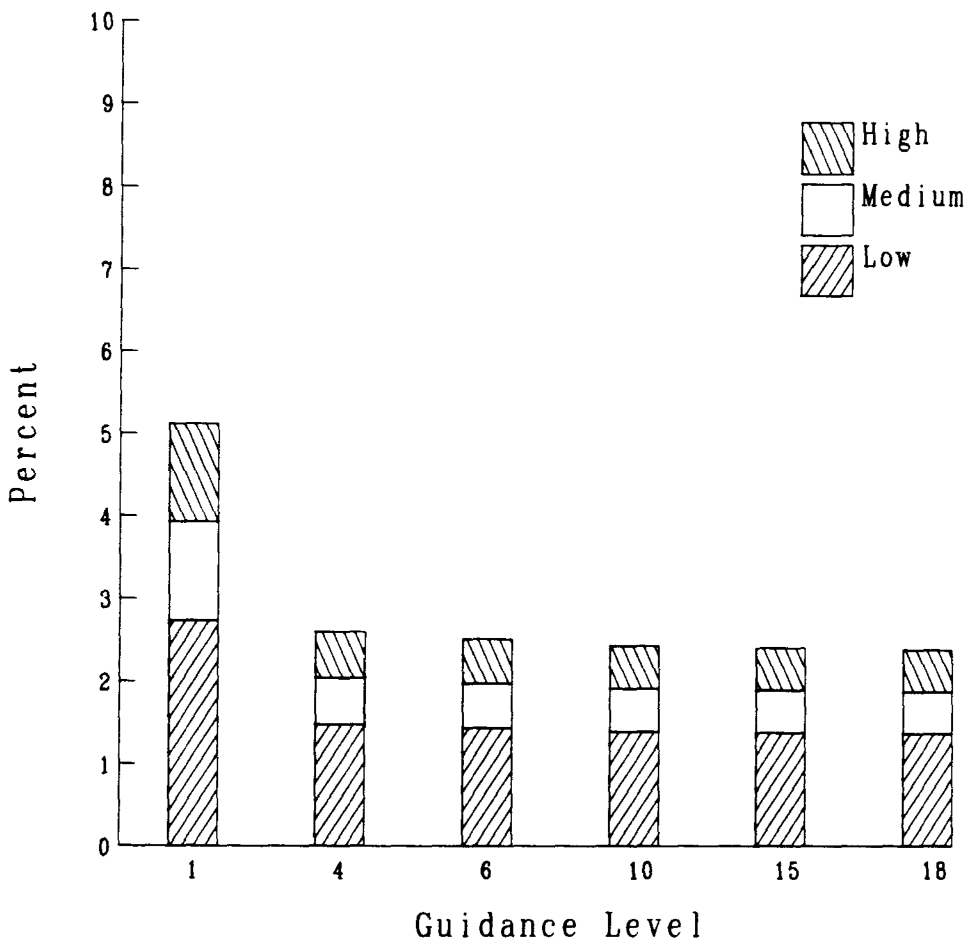


Figure 32. The percentage reduction in the net profit of the average profitable AM radio broadcast station associated with the maximum annual cash flow cost of compliance with guidelines limiting public exposure to radiofrequency radiation is shown for 6 of 18 guidance levels at 3 cost levels.

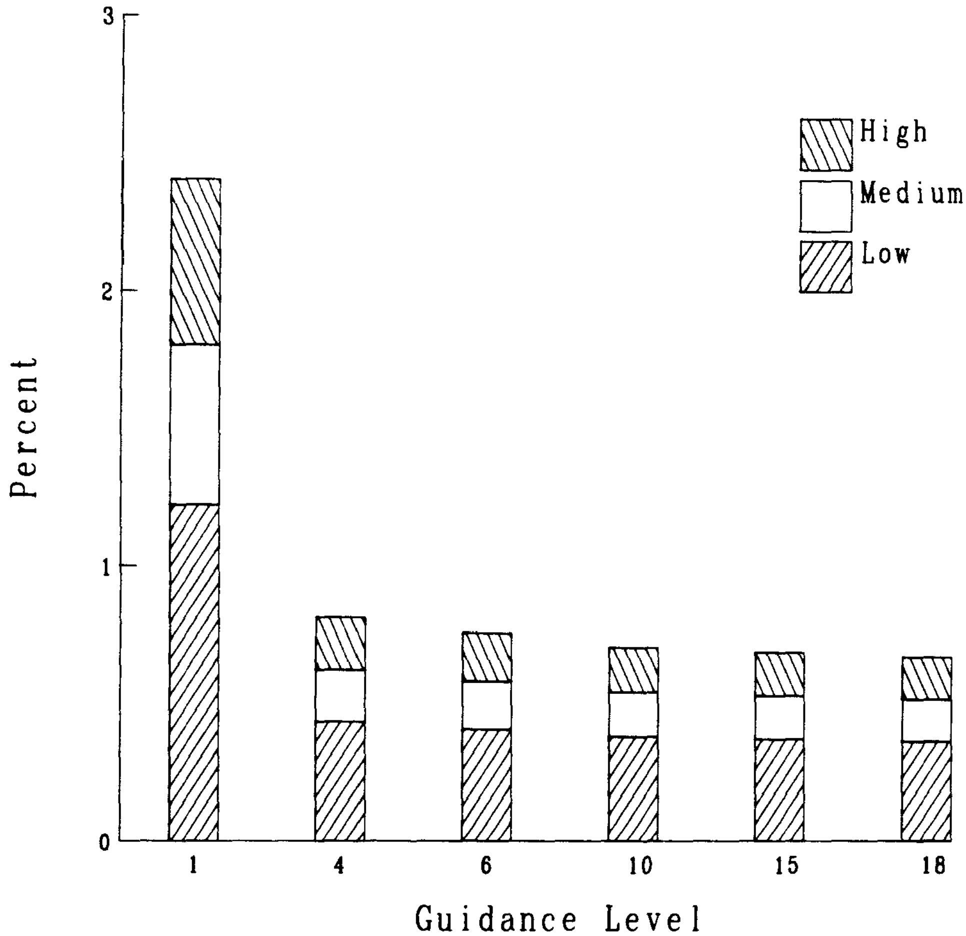


Figure 33. The percentage reduction in the net profit of the average profitable AM radio broadcast station associated with the average annual cash flow cost of compliance with guidelines limiting public exposure to radiofrequency radiation is shown for 6 of 18 guidance levels at 3 cost levels.

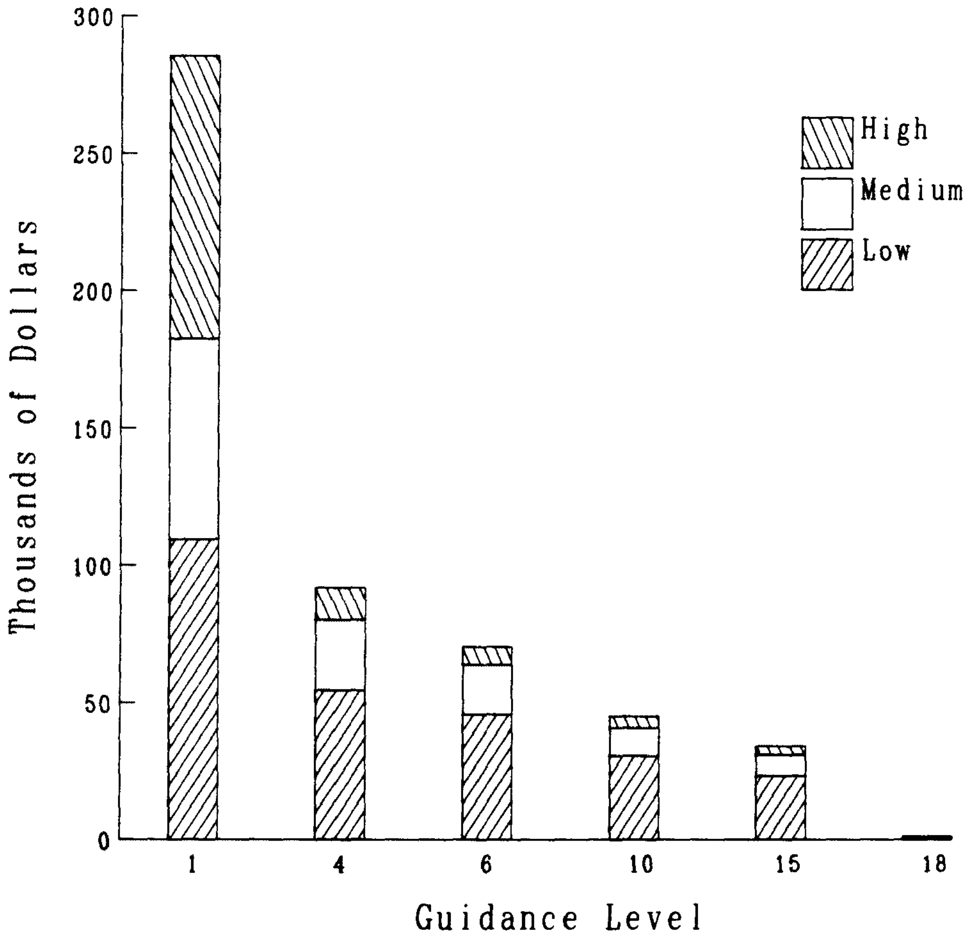


Figure 34. The range of the average (of 5 cohorts) present (constant dollar) value of the net after-tax cost to the average profitable TV broadcast station of guidelines limiting public exposure to radiofrequency radiation is shown for 6 of 18 guidance levels studied.

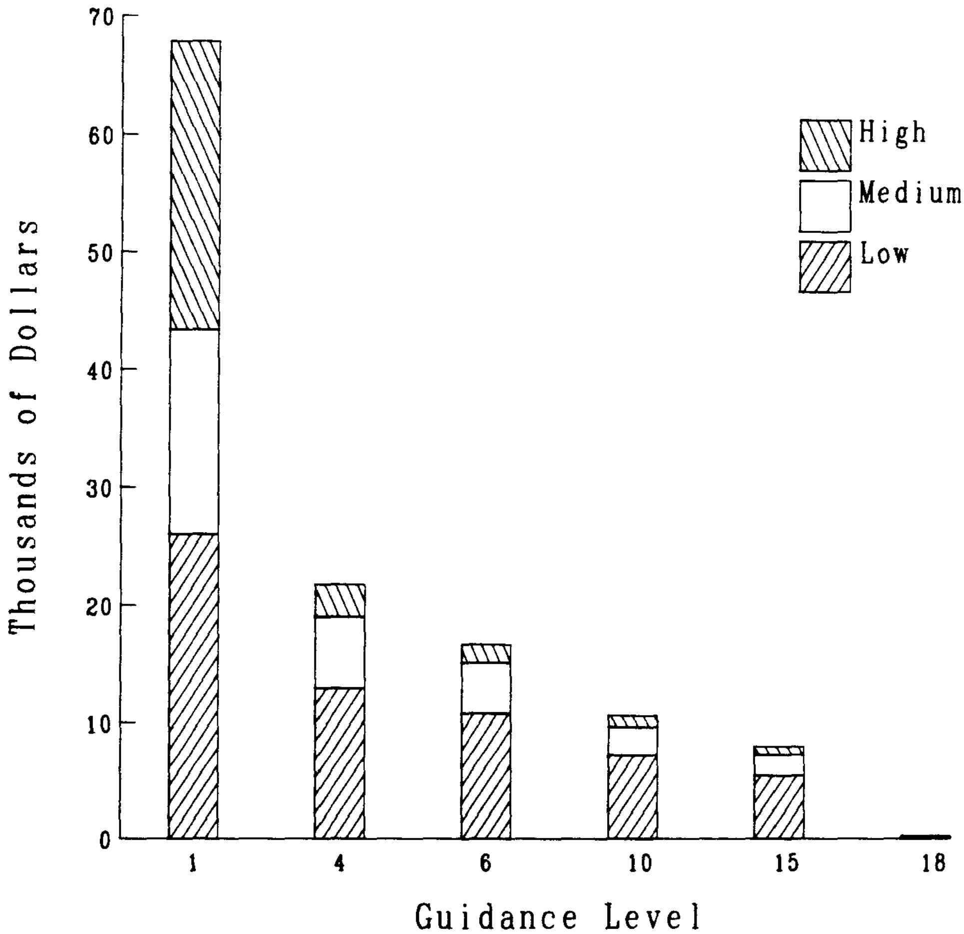


Figure 35. The range of average annual net after-tax cash flow (current year dollar) cost to the average profitable TV broadcast station of guidelines limiting public exposure to radio-frequency radiation is shown for 6 of 18 guidance levels studied.

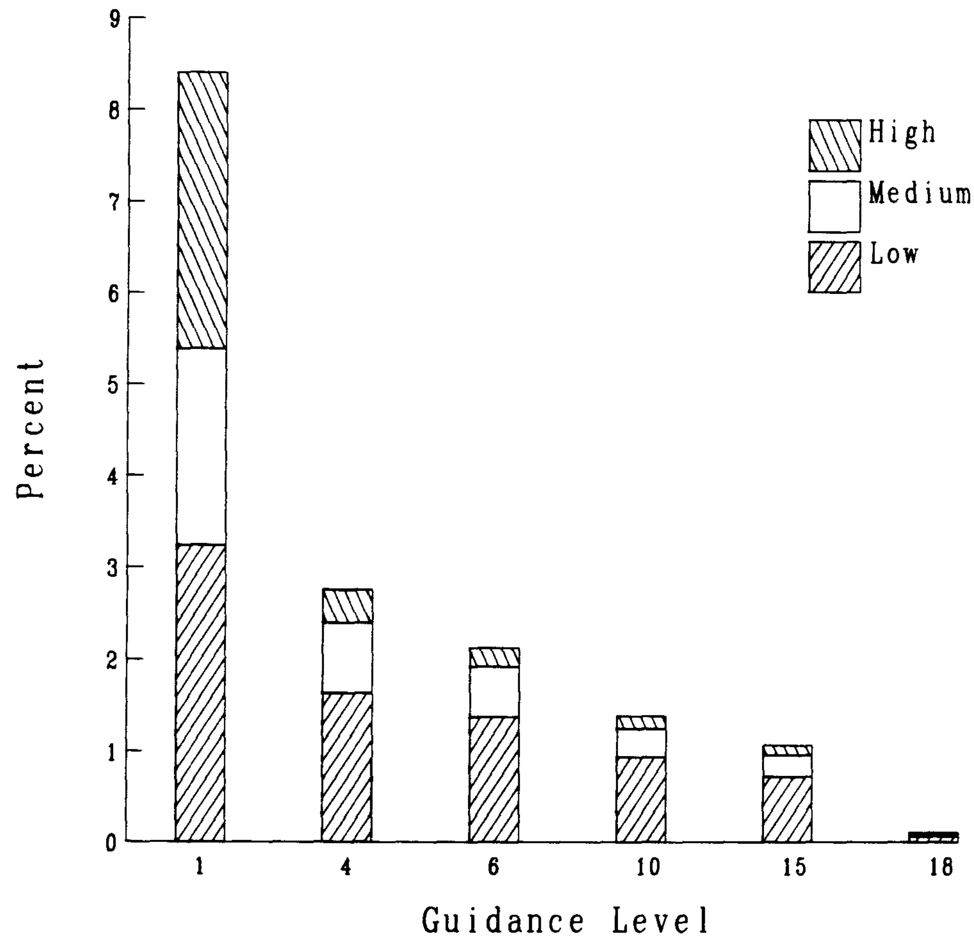


Figure 36. The percentage reduction in the net profit of the average profitable TV broadcast station associated with the maximum annual cash flow cost of compliance with guidelines limiting public exposure to radiofrequency radiation is shown for 6 of 18 guidance levels studied.

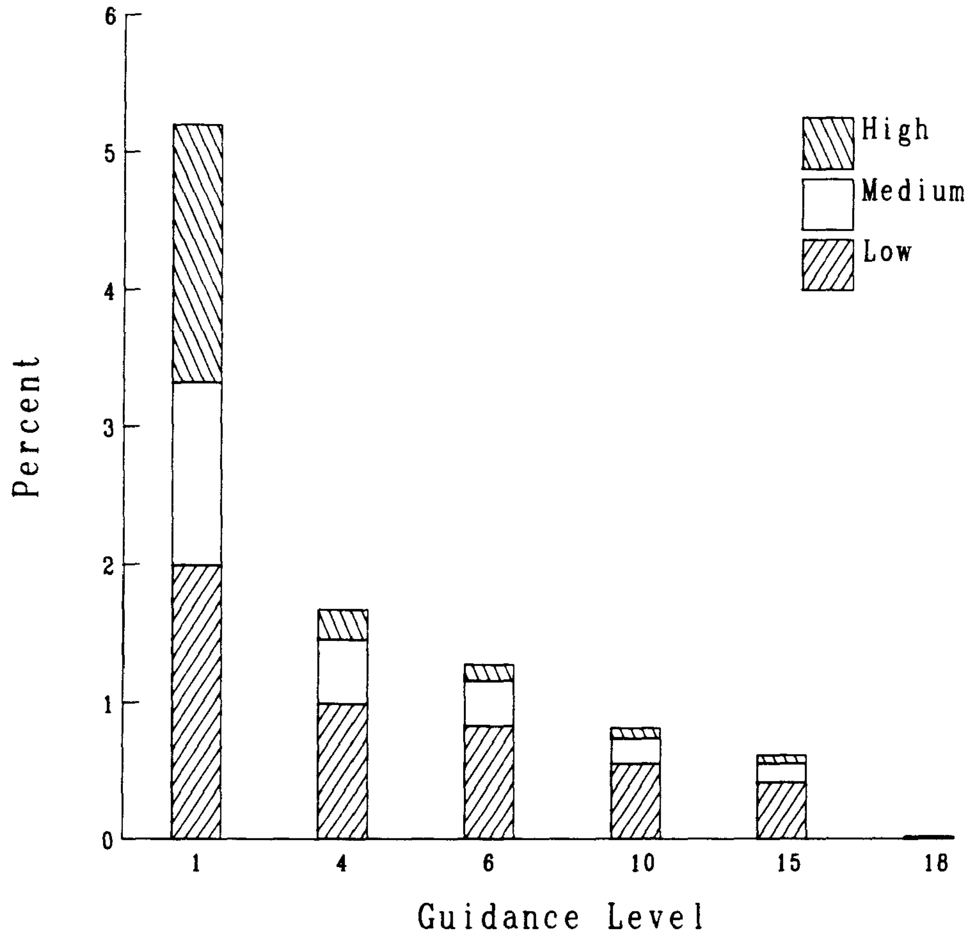
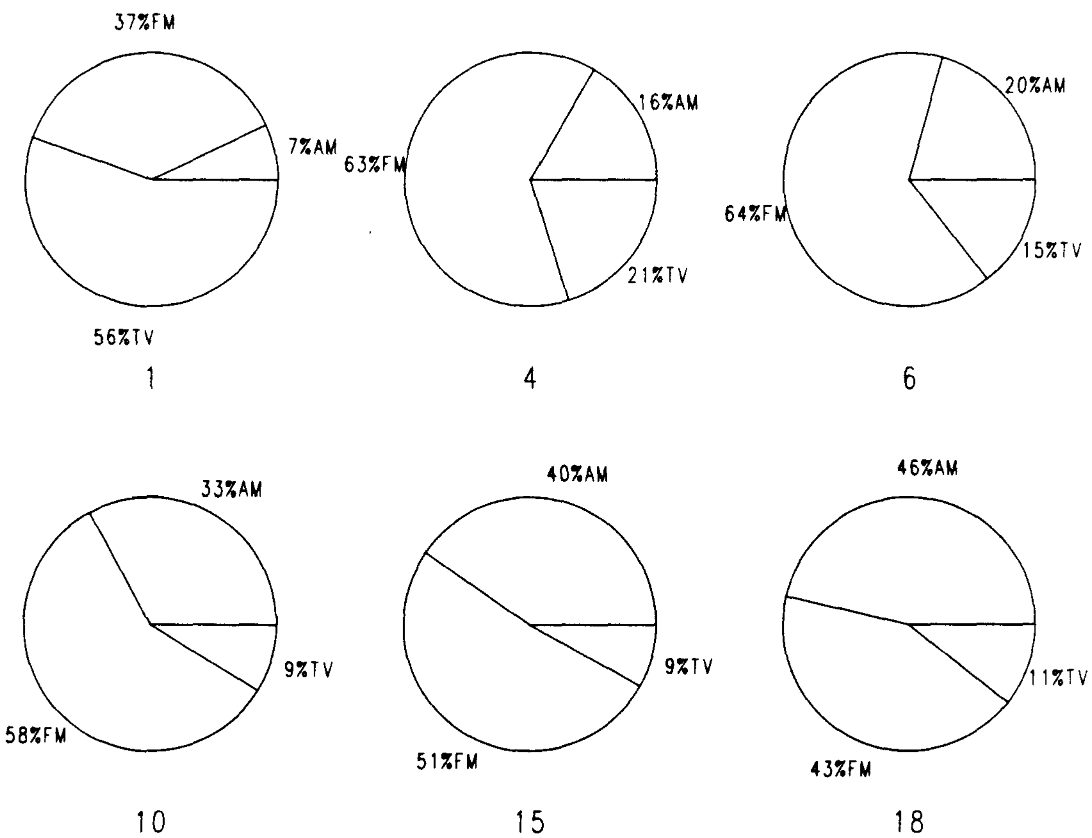


Figure 37. The percentage reduction in the net profit of the average profitable TV broadcast station associated with the average annual cash flow cost of compliance with guidelines limiting public exposure to radiofrequency radiation is shown for 6 of 18 guidance levels studied.



Guidance Level

Figure 38. The distribution of the total present (constant dollar) value cost to society-at-large among AM, FM, and TV broadcasters of guidelines limiting public exposure to radiofrequency radiation is shown for 6 of 18 guidance levels studied (medium cost analysis).

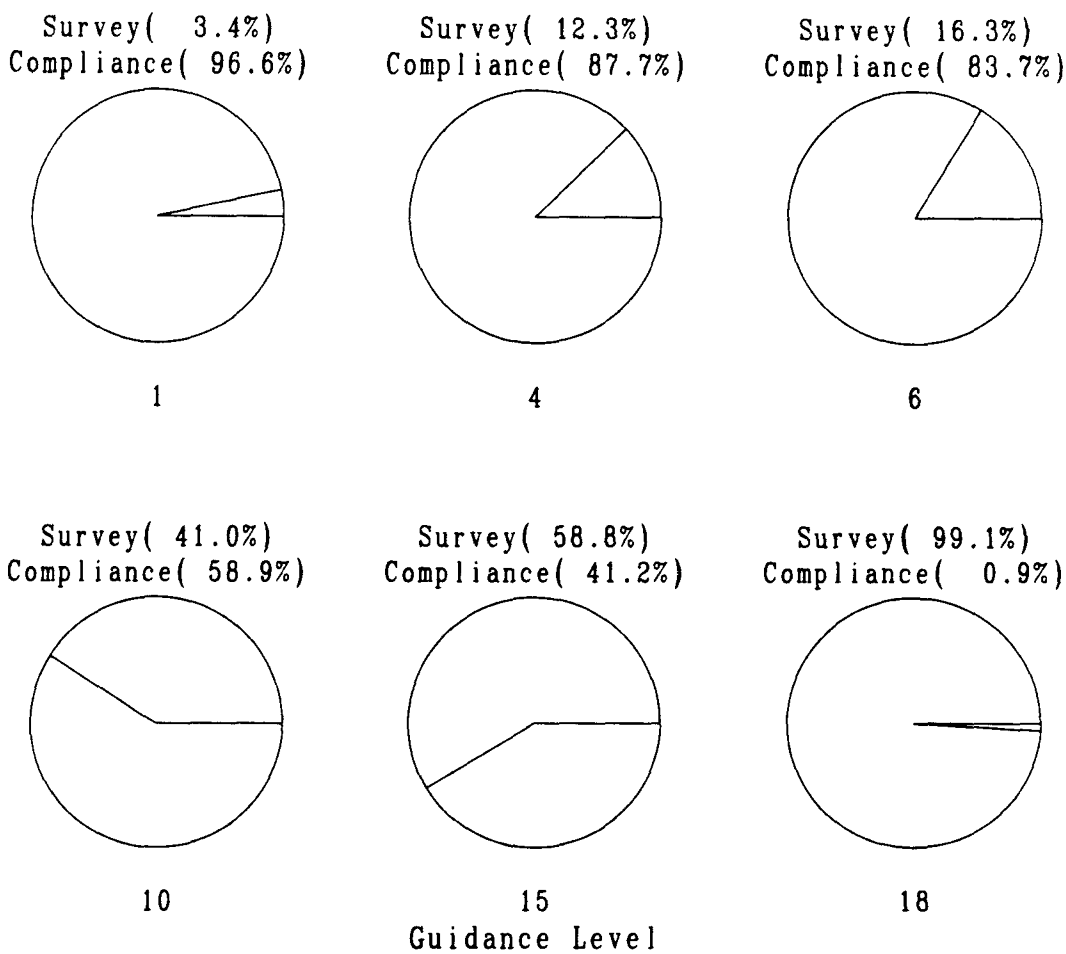


Figure 39. The distribution of the two main cost components for the total gross (undiscounted) cost to society-at-large of guidelines limiting public exposure to radiofrequency radiation from FM broadcast sources is shown for 6 of 18 guidance levels studied (medium cost analysis).

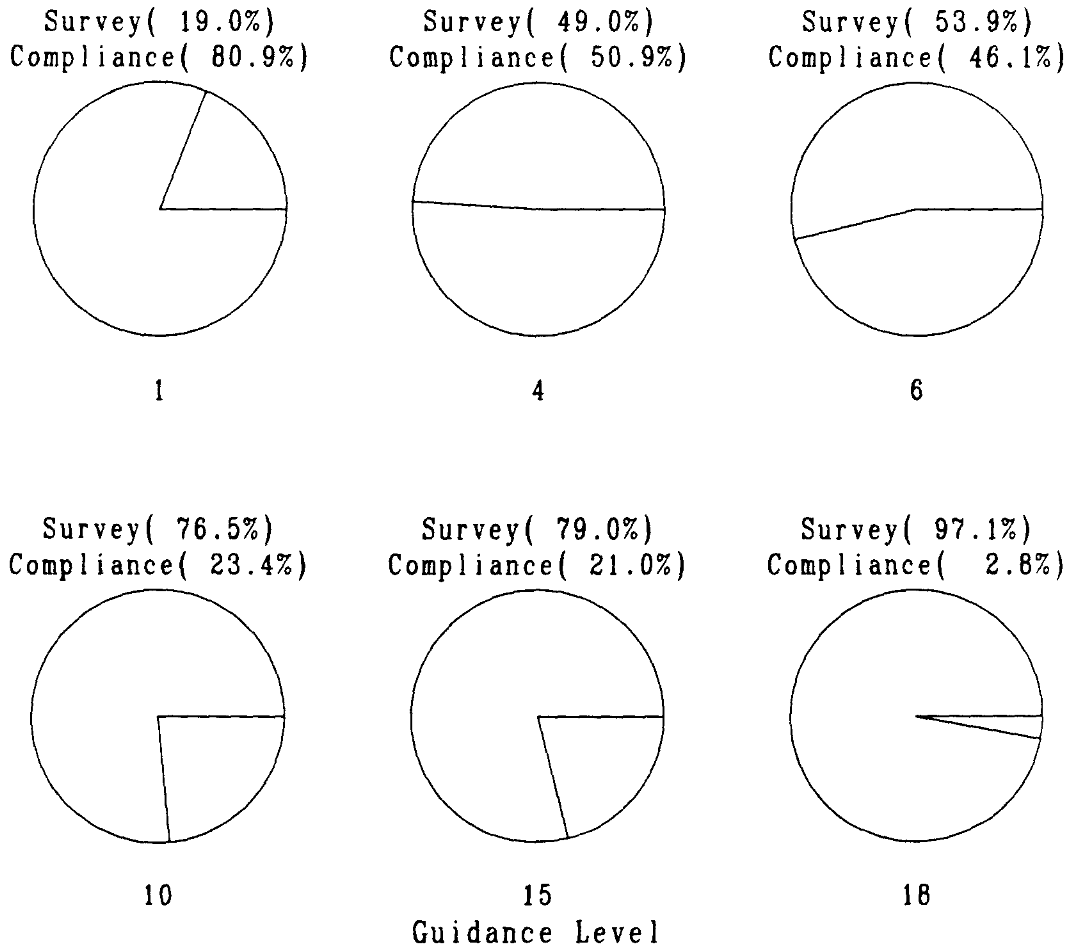


Figure 40. The distribution of the two main cost components for the total gross (undiscounted) cost to society-at-large of guidelines limiting public exposure to radiofrequency radiation from AM broadcast sources is shown for 6 of 18 guidance levels studied (medium cost analysis).

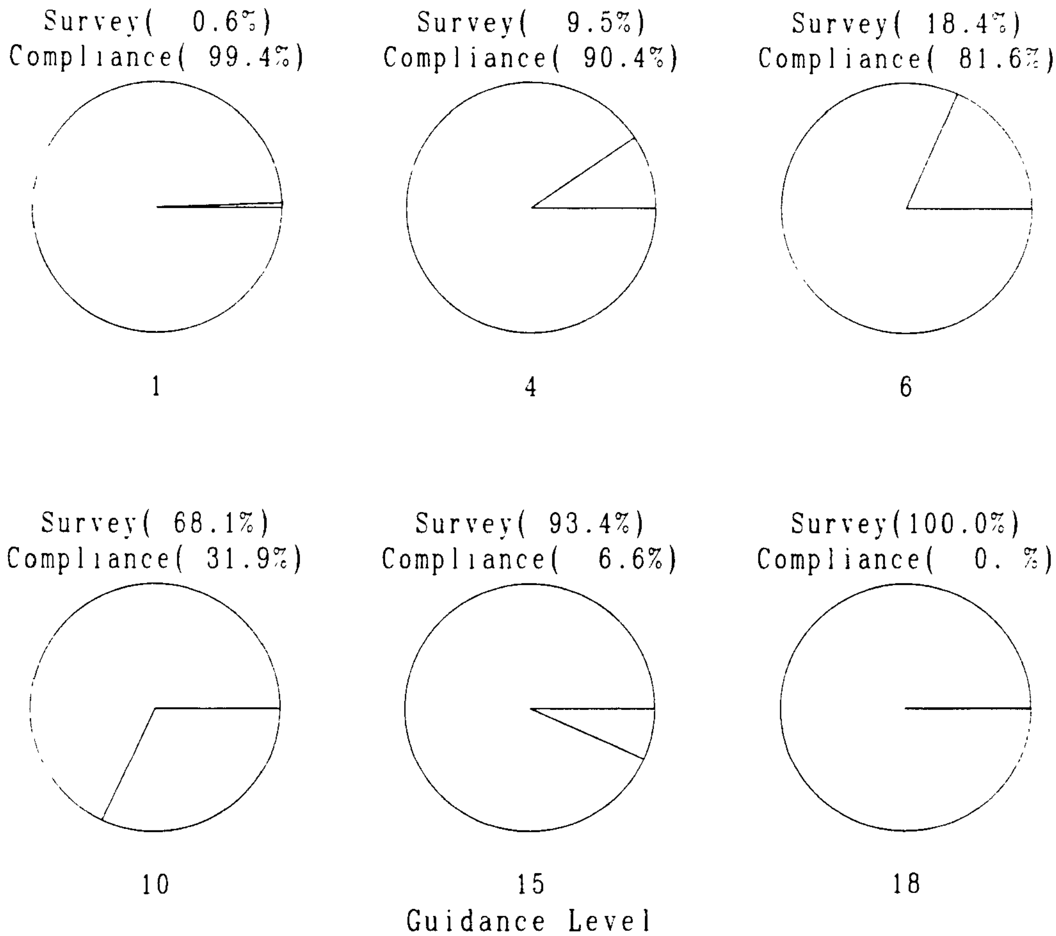


Figure 41. The distribution of the two main cost components for the total gross (undiscounted) cost to society-at-large of guidelines limiting public exposure to radiofrequency radiation from TV broadcast sources is shown for 6 of 18 guidance levels studied (medium cost analysis).

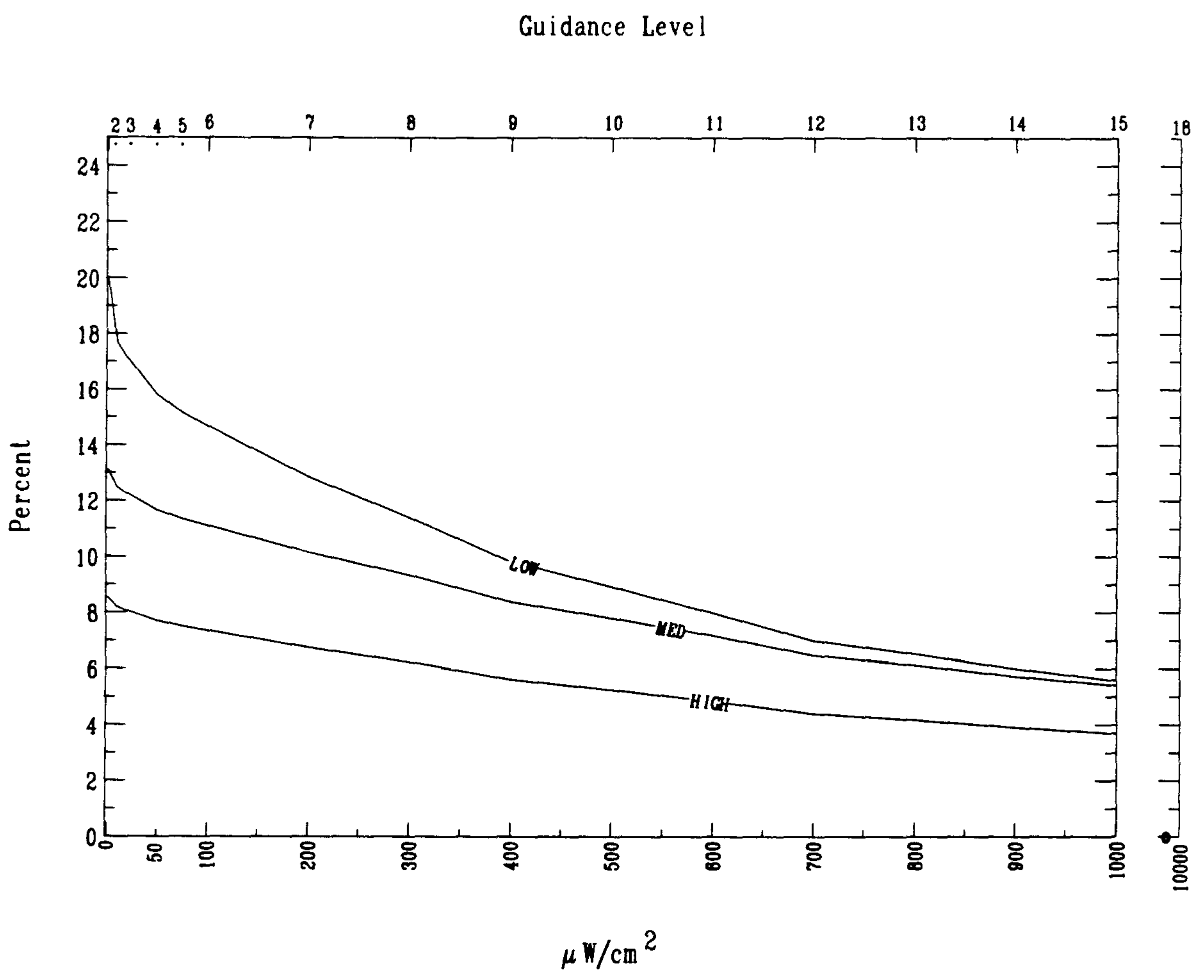


Figure 42. The present (constant dollar) value of the cost to society-at-large of guidelines limiting public exposure to radiofrequency radiation from FM radio broadcast sources is reduced by the percentages shown if compliance measure one is permitted.

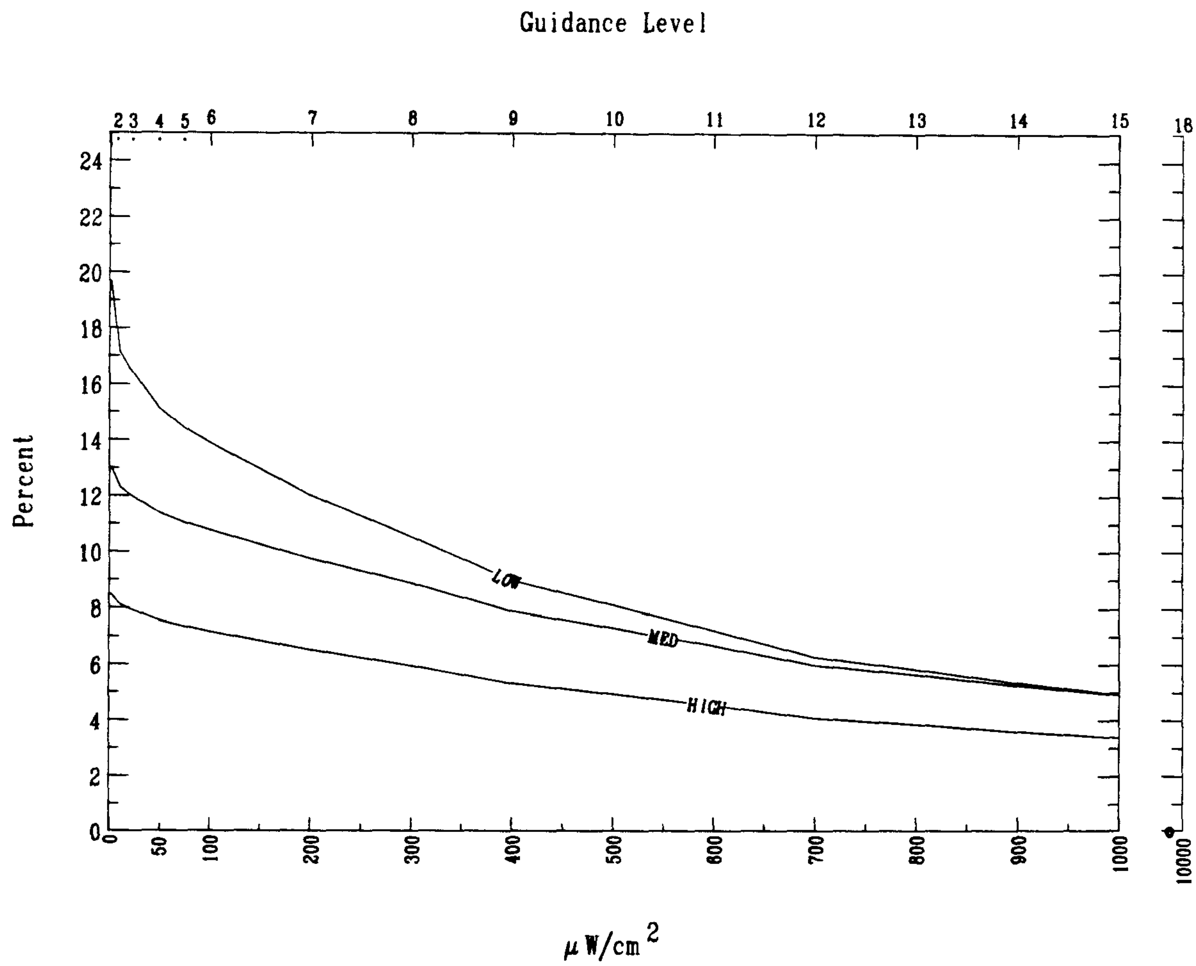


Figure 43. The present (constant dollar) value of the net after-tax cost to the FM broadcast industry of guidelines limiting public exposure to radiofrequency radiation is reduced by the percentages shown if compliance measure one is permitted.

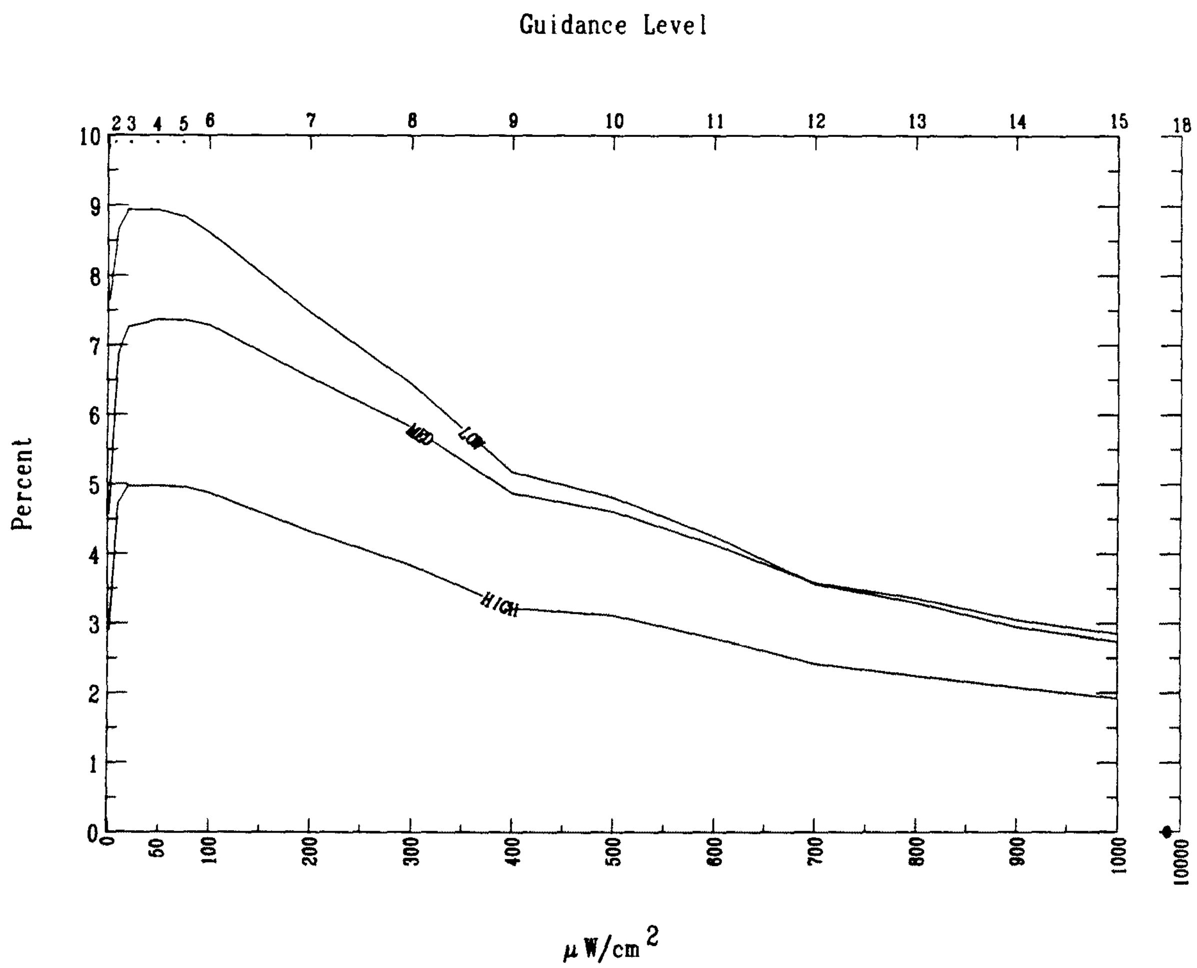


Figure 44. The total present (constant dollar) value of the cost to society-at-large of guidelines limiting public exposure to radiofrequency radiation from AM, FM, and TV broadcast sources is reduced by the percentages shown if compliance measure one is permitted for FM stations.

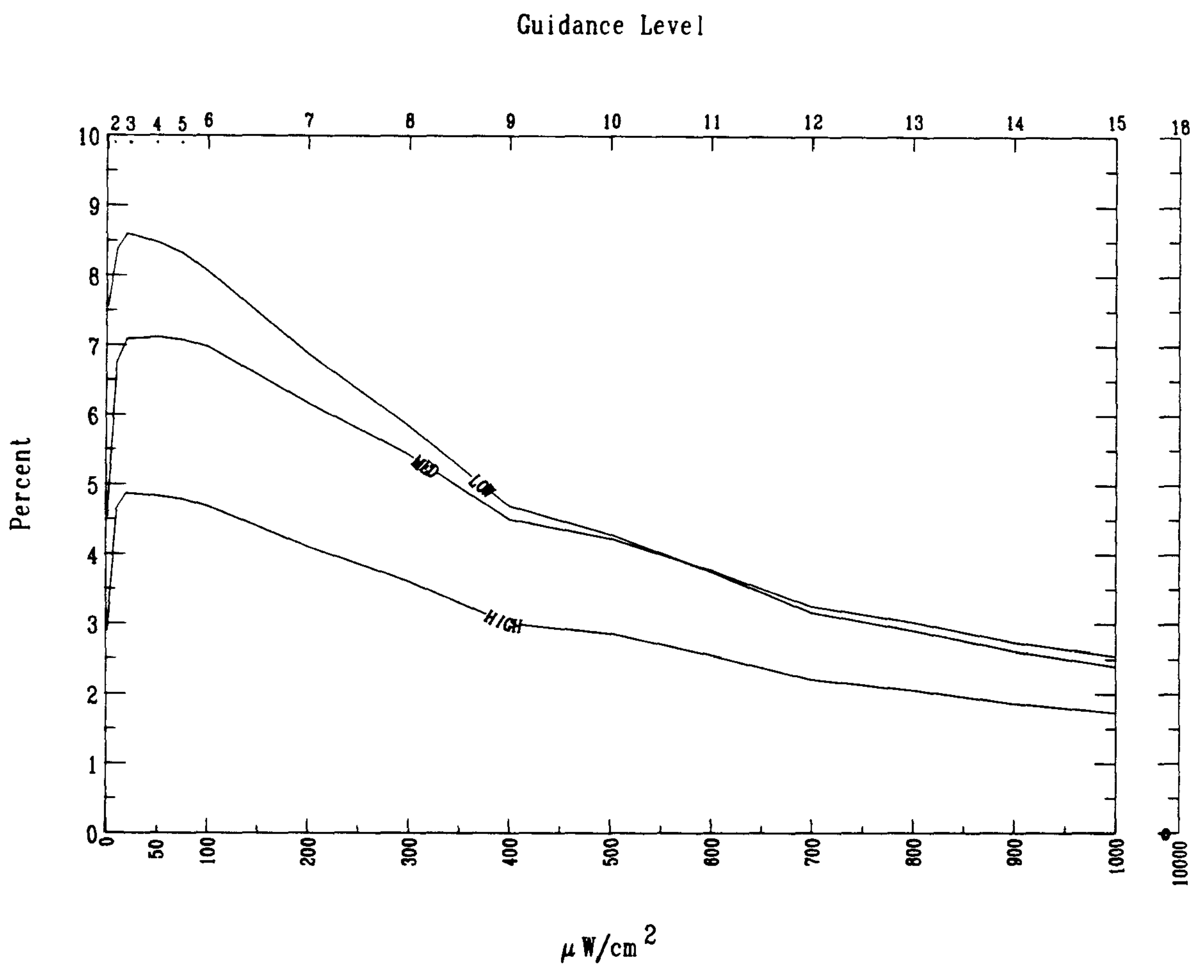
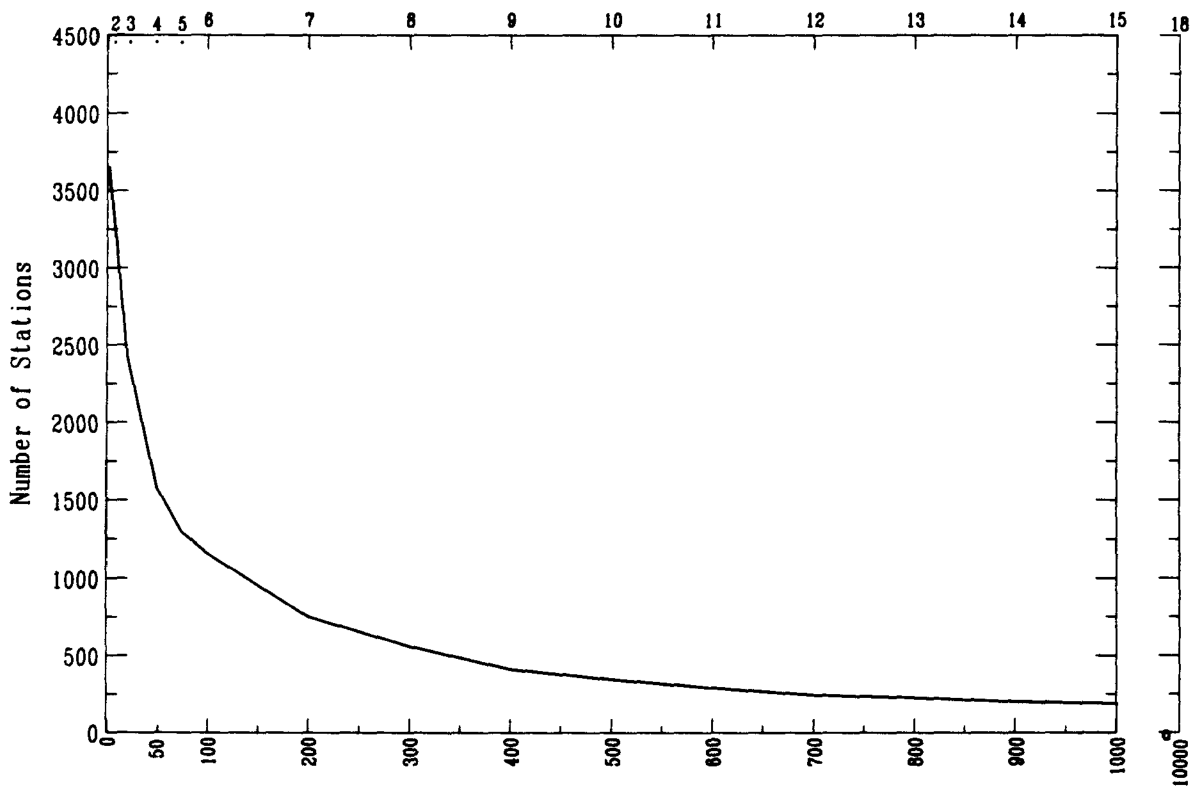


Figure 45. The total present (constant dollar) value of the cost to the AM, FM, and TV broadcast industry of guidelines limiting public exposure to radiofrequency radiation is reduced by the percentages shown if compliance measure one is permitted for FM stations.

Guidance Level



μW/cm²

Figure 46. The number of FM radio broadcast stations requiring measures to comply with guidelines limiting public exposure to radiofrequency radiation is shown for 18 specified guidance levels.

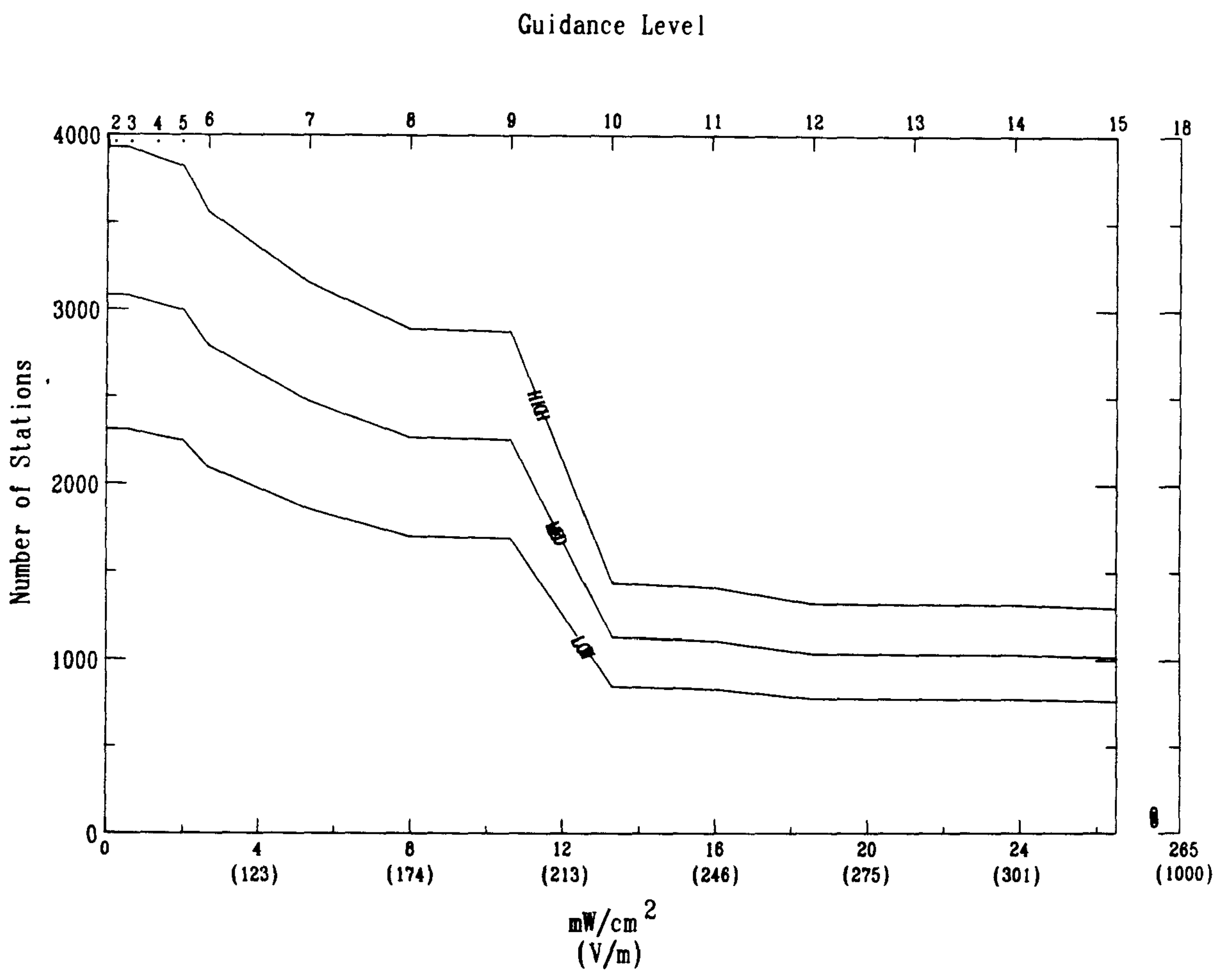


Figure 47. The number of AM radio broadcast stations requiring measures to comply with guidelines limiting public exposure to radiofrequency radiation is shown for 18 specified guidance levels at three cost levels.

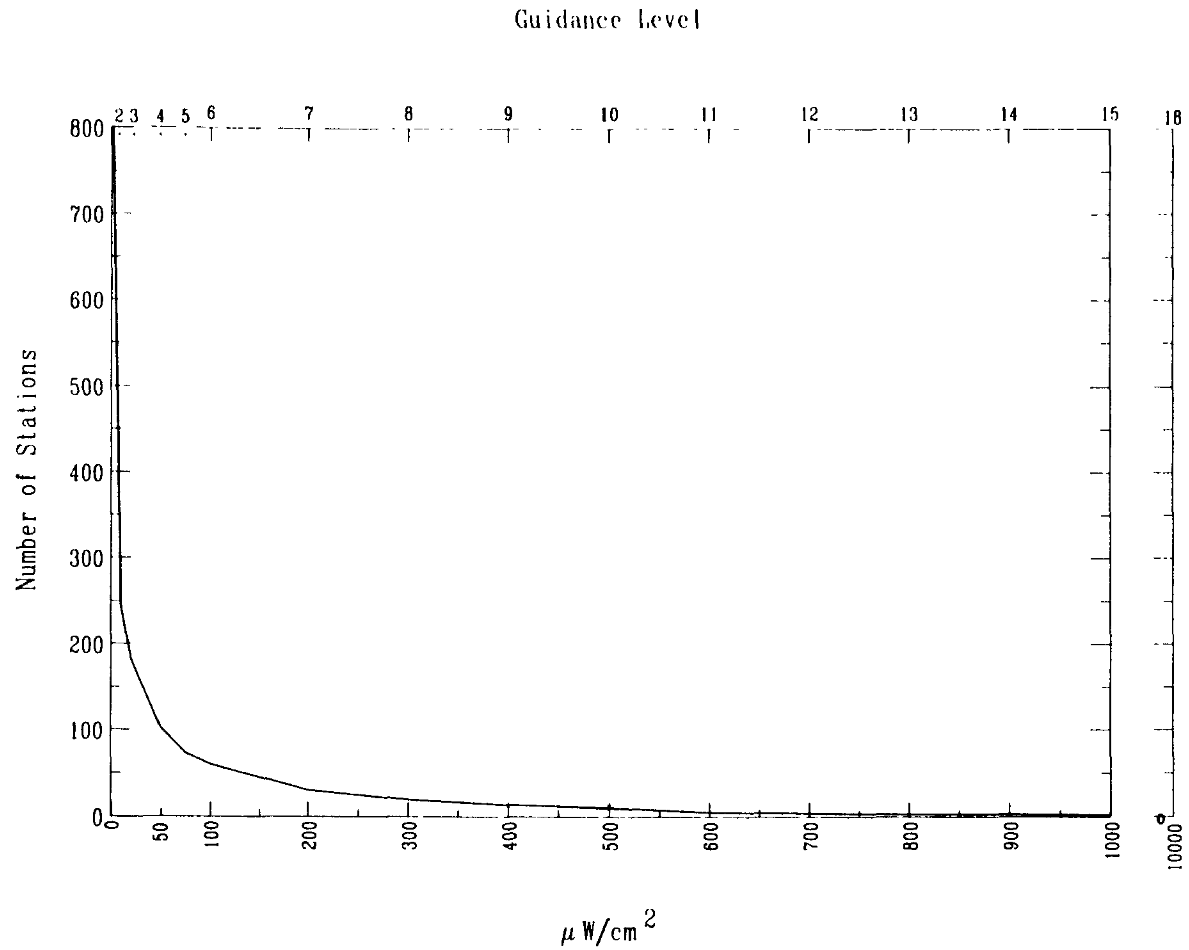


Figure 48. The number of TV broadcast stations requiring measures to comply with guidelines limiting public exposure to radiofrequency radiation is shown for 18 specified guidance levels.

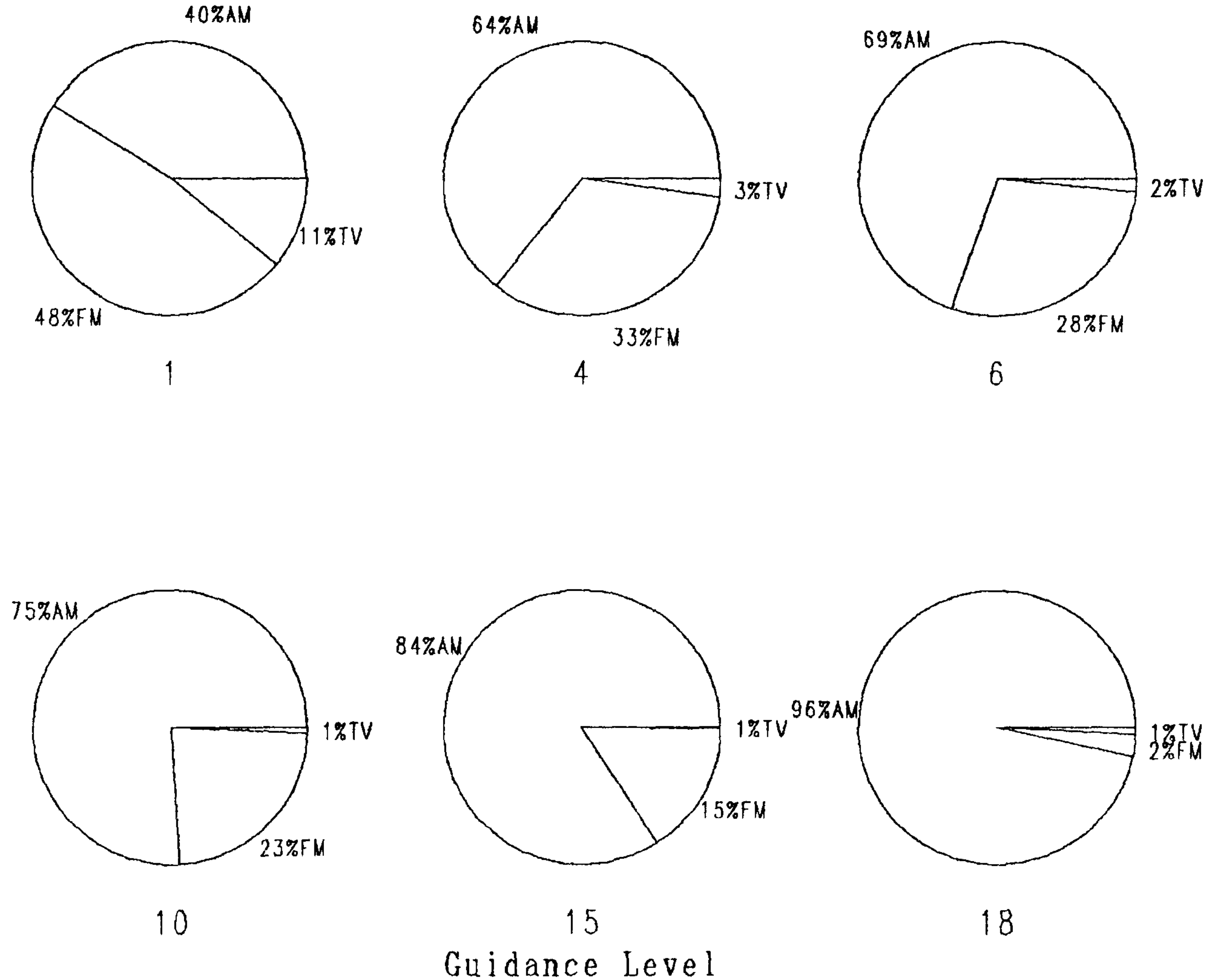


Figure 49. The percentage distribution of AM, FM and TV broadcast stations requiring compliance measures is shown for 6 of 18 guidance levels studied (medium cost analysis).

TABLE 12. AN ESTIMATE OF THE POTENTIAL COST TO THE SOCIETY-AT-LARGE OF GUIDELINES LIMITING PUBLIC EXPOSURE TO RADIOFREQUENCY RADIATION FROM AM, FM, VHF-TV, AND UHF-TV BROADCAST SOURCES IS GIVEN FOR 3 COST LEVELS. THE ANNUAL CASH FLOW (CURRENT YEAR DOLLAR) COST AND THE PRESENT (CONSTANT DOLLAR) VALUE ARE SHOWN FOR COMPLIANCE WITH 18 SPECIFIED GUIDANCE LEVELS. IT IS ASSUMED THAT FM STATIONS SELECT ONE OF FIVE COMPLIANCE MEASURES (2 THROUGH 6) AND THAT COMPLIANCE COSTS (ANNUAL CASH FLOW) ARE SPREAD EVENLY AMONG FIVE ANNUAL COHORTS OF STATIONS. NUMBERS ARE IN MILLIONS OF DOLLARS. MICROWATTS PER SQ. CM IS ABBREVIATED UW/CM^2; VOLTS PER METER, V/M.

	FM			AM			TV			TOTAL		
GUIDANCE LEVEL	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
1.		1. UW/CM^2			10. V/M			1. UW/CM^2				
ANNUAL CASH FLOW COST	30.0	51.5	73.3	5.3	9.7	15.7	45.6	76.0	118.9	80.9	137.2	207.8
PRESENT VALUE	125.1	214.7	305.5	22.2	40.5	65.4	190.2	317.0	495.7	337.5	572.2	866.6
2.		10. UW/CM^2			32. V/M			10. UW/CM^2				
ANNUAL CASH FLOW COST	13.0	28.0	39.4	3.0	5.1	7.8	10.8	16.9	20.5	26.8	49.9	67.7
PRESENT VALUE	54.3	116.6	164.3	12.5	21.1	32.3	45.1	70.5	85.5	111.8	208.2	282.2
3.		20. UW/CM^2			45. V/M			20. UW/CM^2				
ANNUAL CASH FLOW COST	10.4	21.9	30.5	2.7	4.4	6.7	7.0	10.3	12.0	20.0	36.5	49.1
PRESENT VALUE	43.2	91.3	127.1	11.1	18.4	27.8	29.3	42.8	50.1	83.6	152.4	204.9
4.		50. UW/CM^2			71. V/M			50. UW/CM^2				
ANNUAL CASH FLOW COST	6.9	14.3	19.6	2.3	3.8	5.6	3.1	4.5	5.2	12.4	22.6	30.4
PRESENT VALUE	28.8	59.5	81.6	9.8	15.7	23.3	13.0	18.9	21.9	51.6	94.1	126.7
5.		75. UW/CM^2			87. V/M			75. UW/CM^2				
ANNUAL CASH FLOW COST	5.9	12.0	16.4	2.3	3.6	5.3	2.1	3.0	3.4	10.2	18.5	25.0
PRESENT VALUE	24.5	49.9	68.2	9.4	15.0	22.0	8.7	12.3	14.0	42.6	77.2	104.1

TABLE 12. (CONTINUED)

GUIDANCE LEVEL	FM LOW	FM MED	FM HIGH	AM LOW	AM MED	AM HIGH	TV LOW	TV MED	TV HIGH	TOTAL LOW	TOTAL MED	TOTAL HIGH
6.		100. UW/CM^2			100. V/M			100. UW/CM^2				
ANNUAL CASH FLOW COST	5.3	10.7	14.5	2.2	3.4	5.0	1.7	2.3	2.6	9.2	16.5	22.1
PRESENT VALUE	22.2	44.7	60.4	9.1	14.3	20.9	7.1	9.8	11.0	38.4	68.8	92.3
7.		200. UW/CM^2			141. V/M			200. UW/CM^2				
ANNUAL CASH FLOW COST	3.9	7.5	10.0	2.1	3.2	4.6	0.8	1.1	1.3	6.8	11.8	15.9
PRESENT VALUE	16.2	31.2	41.6	8.6	13.4	19.3	3.5	4.7	5.4	28.3	49.3	66.3
8.		300. UW/CM^2			173. V/M			300. UW/CM^2				
ANNUAL CASH FLOW COST	3.2	5.9	7.8	2.0	3.0	4.2	0.6	0.8	1.0	5.8	9.7	13.0
PRESENT VALUE	13.3	24.7	32.7	8.1	12.4	17.7	2.6	3.4	4.0	24.0	40.6	54.4
9.		400. UW/CM^2			200. V/M			400. UW/CM^2				
ANNUAL CASH FLOW COST	2.7	4.8	6.3	1.9	3.0	4.2	0.5	0.7	0.8	5.1	8.4	11.3
PRESENT VALUE	11.1	19.9	26.2	8.1	12.3	17.5	2.2	2.9	3.5	21.4	35.1	47.1
10.		500. UW/CM^2			224. V/M			500. UW/CM^2				
ANNUAL CASH FLOW COST	2.4	4.3	5.6	1.7	2.4	3.3	0.5	0.6	0.8	4.6	7.3	9.6
PRESENT VALUE	10.2	17.8	23.3	7.0	10.1	13.7	2.0	2.6	3.2	19.1	30.5	40.1

TABLE 12. (CONTINUED)

GUIDANCE LEVEL	FM			AM			TV			TOTAL		
	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
11.		600. UW/CM^2			245. V/M			600. UW/CM^2				
ANNUAL CASH FLOW COST	2.2	3.8	5.0	1.7	2.4	3.2	0.4	0.5	0.6	4.3	6.7	8.9
PRESENT VALUE	9.4	16.0	20.8	6.9	10.0	13.5	1.6	2.1	2.6	17.9	28.1	36.9
12.		700. UW/CM^2			265. V/M			700. UW/CM^2				
ANNUAL CASH FLOW COST	2.1	3.4	4.5	1.6	2.4	3.2	0.4	0.5	0.6	4.1	6.3	8.3
PRESENT VALUE	8.6	14.3	18.6	6.8	9.8	13.3	1.5	2.1	2.5	17.0	26.2	34.4
13.		800. UW/CM^2			282. V/M			800. UW/CM^2				
ANNUAL CASH FLOW COST	2.0	3.3	4.2	1.6	2.3	3.2	0.4	0.5	0.6	4.0	6.1	8.0
PRESENT VALUE	8.3	13.7	17.7	6.8	9.8	13.2	1.5	2.0	2.5	16.6	25.5	33.4
14.		900. UW/CM^2			300. V/M			900. UW/CM^2				
ANNUAL CASH FLOW COST	1.9	3.1	4.0	1.6	2.3	3.2	0.4	0.5	0.6	3.9	5.9	7.8
PRESENT VALUE	8.0	12.9	16.7	6.8	9.8	13.2	1.5	2.0	2.5	16.3	24.7	32.4
15.		1000. UW/CM^2			316. V/M			1000. UW/CM^2				
ANNUAL CASH FLOW COST	1.9	3.0	3.8	1.6	2.3	3.1	0.3	0.5	0.6	3.8	5.8	7.6
PRESENT VALUE	7.8	12.4	16.0	6.8	9.8	13.1	1.4	1.9	2.4	16.0	24.1	31.5

TABLE 12. (CONTINUED)

GUIDANCE LEVEL	FM LOW	FM MED	FM HIGH	AM LOW	AM MED	AM HIGH	TV LOW	TV MED	TV HIGH	TOTAL LOW	TOTAL MED	TOTAL HIGH
16.		2000. UW/CM^2			447. V/M			2000. UW/CM^2				
ANNUAL CASH FLOW COST	1.6	2.3	2.9	1.6	2.3	3.1	0.3	0.4	0.5	3.5	5.0	6.6
PRESENT VALUE	6.5	9.6	12.2	6.7	9.6	12.8	1.4	1.8	2.3	14.6	21.0	27.3
17.		5000. UW/CM^2			708. V/M			5000. UW/CM^2				
ANNUAL CASH FLOW COST	1.4	1.9	2.4	1.4	2.0	2.5	0.3	0.4	0.5	3.1	4.3	5.4
PRESENT VALUE	5.7	7.8	9.8	6.0	8.2	10.4	1.4	1.8	2.3	13.1	17.8	22.5
18.		10000. UW/CM^2			1000. V/M			10000. UW/CM^2				
ANNUAL CASH FLOW COST	1.3	1.8	2.2	1.4	1.9	2.4	0.3	0.4	0.5	3.1	4.1	5.2
PRESENT VALUE	5.5	7.4	9.2	5.9	7.9	10.0	1.4	1.8	2.3	12.7	17.1	21.5

TABLE 13. AN ESTIMATE OF THE POTENTIAL COST TO THE BROADCAST INDUSTRY OF GUIDELINES LIMITING PUBLIC EXPOSURE TO RADIOFREQUENCY RADIATION FROM AM, FM, VHF-TV, AND UHF-TV BROADCAST SOURCES IS GIVEN FOR 3 COST LEVELS. THE AVERAGE ANNUAL CASH FLOW (CURRENT YEAR DOLLAR) COSTS AND THE PRESENT (CONSTANT DOLLAR) VALUE ARE SHOWN FOR COMPLIANCE WITH 18 SPECIFIED GUIDANCE LEVELS. IT IS ASSUMED THAT FM STATIONS SELECT ONE OF FIVE COMPLIANCE MEASURES (2 THROUGH 6) AND THAT COMPLIANCE COSTS (ANNUAL NET CASH FLOW) ARE SPREAD EVENLY AMONG FIVE ANNUAL COHORTS OF STATIONS. NUMBERS ARE IN MILLIONS OF DOLLARS. MICROWATTS PER SQ. CM IS ABBREVIATED UW/CM^2; VOLTS PER METER, V/M.

	FM			AM			TV			TOTAL		
GUIDANCE LEVEL	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
1.		1. UW/CM^2			10. V/M			1. UW/CM^2				
AVG ANNUAL CASH FLOW	8.5	14.8	21.3	1.5	2.7	4.4	12.8	21.3	33.4	22.8	38.8	59.1
PRESENT VALUE	59.9	103.7	149.1	10.9	19.6	31.5	89.8	149.6	233.9	160.5	273.0	414.6
2.		10. UW/CM^2			32. V/M			10. UW/CM^2				
AVG ANNUAL CASH FLOW	3.7	7.9	11.2	0.8	1.4	2.2	3.0	4.7	5.8	7.5	14.1	19.1
PRESENT VALUE	26.1	56.0	79.2	6.3	10.5	15.9	21.3	33.4	40.5	53.7	99.8	135.6
3.		20. UW/CM^2			45. V/M			20. UW/CM^2				
AVG ANNUAL CASH FLOW	2.9	6.2	8.7	0.7	1.2	1.8	2.0	2.9	3.4	5.6	10.3	13.9
PRESENT VALUE	20.8	43.9	61.2	5.6	9.2	13.8	13.9	20.3	23.8	40.4	73.3	98.8
4.		50. UW/CM^2			71. V/M			50. UW/CM^2				
AVG ANNUAL CASH FLOW	1.9	4.0	5.5	0.6	1.0	1.5	0.9	1.3	1.5	3.4	6.3	8.5
PRESENT VALUE	14.0	28.7	39.4	5.0	7.9	11.6	6.2	9.1	10.5	25.2	45.7	61.5
5.		75. UW/CM^2			87. V/M			75. UW/CM^2				
AVG ANNUAL CASH FLOW	1.6	3.4	4.6	0.6	1.0	1.5	0.6	0.8	0.9	2.8	5.2	7.0
PRESENT VALUE	12.0	24.1	33.0	4.8	7.6	11.0	4.2	5.9	6.8	21.0	37.7	50.8

TABLE 13. (CONTINUED)

GUIDANCE LEVEL	FM LOW	FM MED	FM HIGH	AM LOW	AM MED	AM HIGH	TV LOW	TV MED	TV HIGH	TOTAL LOW	TOTAL MED	TOTAL HIGH
6.		100. UW/CM^2			100. V/M			100. UW/CM^2				
AVG ANNUAL CASH FLOW	1.5	3.0	4.1	0.6	0.9	1.4	0.5	0.7	0.7	2.6	4.6	6.2
PRESENT VALUE	10.9	21.7	29.2	4.7	7.3	10.5	3.4	4.7	5.4	19.0	33.7	45.1
7.		200. UW/CM^2			141. V/M			200. UW/CM^2				
AVG ANNUAL CASH FLOW	1.1	2.1	2.8	0.6	0.9	1.3	0.2	0.3	0.4	1.9	3.3	4.4
PRESENT VALUE	8.0	15.2	20.3	4.5	6.8	9.8	1.7	2.3	2.7	14.2	24.4	32.8
8.		300. UW/CM^2			173. V/M			300. UW/CM^2				
AVG ANNUAL CASH FLOW	0.9	1.6	2.2	0.5	0.8	1.2	0.2	0.2	0.3	1.6	2.7	3.6
PRESENT VALUE	6.6	12.2	16.0	4.2	6.4	9.0	1.3	1.7	2.1	12.2	20.3	27.1
9.		400. UW/CM^2			200. V/M			400. UW/CM^2				
AVG ANNUAL CASH FLOW	0.7	1.3	1.7	0.5	0.8	1.2	0.1	0.2	0.2	1.4	2.3	3.1
PRESENT VALUE	5.6	9.9	13.0	4.2	6.3	8.9	1.1	1.5	1.8	11.0	17.7	23.7
10.		500. UW/CM^2			224. V/M			500. UW/CM^2				
AVG ANNUAL CASH FLOW	0.7	1.2	1.5	0.5	0.7	0.9	0.1	0.2	0.2	1.3	2.0	2.6
PRESENT VALUE	5.2	8.9	11.6	3.7	5.3	7.1	1.0	1.4	1.7	9.9	15.5	20.4

TABLE 13. (CONTINUED)

GUIDANCE LEVEL	FM LOW	FM MED	FM HIGH	AM LOW	AM MED	AM HIGH	TV LOW	TV MED	TV HIGH	TOTAL LOW	TOTAL MED	TOTAL HIGH
11.		600. UW/CM^2			245. V/M			600. UW/CM^2				
AVG ANNUAL CASH FLOW	0.6	1.1	1.4	0.5	0.7	0.9	0.1	0.1	0.2	1.2	1.8	2.4
PRESENT VALUE	4.8	8.0	10.4	3.7	5.2	7.0	0.8	1.1	1.4	9.3	14.4	18.9
12.		700. UW/CM^2			265. V/M			700. UW/CM^2				
AVG ANNUAL CASH FLOW	0.6	0.9	1.2	0.4	0.6	0.9	0.1	0.1	0.2	1.1	1.7	2.3
PRESENT VALUE	4.4	7.3	9.4	3.6	5.2	6.9	0.8	1.1	1.3	8.9	13.5	17.7
13.		800. UW/CM^2			282. V/M			800. UW/CM^2				
AVG ANNUAL CASH FLOW	0.5	0.9	1.2	0.4	0.6	0.9	0.1	0.1	0.2	1.1	1.7	2.2
PRESENT VALUE	4.3	6.9	9.0	3.6	5.1	6.9	0.8	1.1	1.3	8.7	13.2	17.2
14.		900. UW/CM^2			300. V/M			900. UW/CM^2				
AVG ANNUAL CASH FLOW	0.5	0.9	1.1	0.4	0.6	0.9	0.1	0.1	0.2	1.1	1.6	2.1
PRESENT VALUE	4.1	6.6	8.5	3.6	5.1	6.9	0.8	1.1	1.3	8.6	12.8	16.7
15.		1000. UW/CM^2			316. V/M			1000. UW/CM^2				
AVG ANNUAL CASH FLOW	0.5	0.8	1.1	0.4	0.6	0.9	0.1	0.1	0.2	1.0	1.6	2.1
PRESENT VALUE	4.0	6.4	8.2	3.6	5.1	6.8	0.8	1.0	1.3	8.4	12.5	16.3

TABLE 13. (CONTINUED)

GUIDANCE LEVEL	FM LOW	FM MED	FM HIGH	AM LOW	AM MED	AM HIGH	TV LOW	TV MED	TV HIGH	TOTAL LOW	TOTAL MED	TOTAL HIGH
16.		2000. UW/CM^2			447. V/M			2000. UW/CM^2				
AVG ANNUAL CASH FLOW	0.4	0.6	0.8	0.4	0.6	0.8	0.1	0.1	0.1	0.9	1.4	1.8
PRESENT VALUE	3.4	5.0	6.4	3.6	5.1	6.7	0.7	1.0	1.2	7.7	11.1	14.3
17.		5000. UW/CM^2			708. V/M			5000. UW/CM^2				
AVG ANNUAL CASH FLOW	0.4	0.5	0.6	0.4	0.5	0.7	0.1	0.1	0.1	0.8	1.2	1.5
PRESENT VALUE	3.1	4.2	5.3	3.2	4.4	5.6	0.7	1.0	1.2	7.0	9.5	12.1
18.		10000. UW/CM^2			1000. V/M			10000. UW/CM^2				
AVG ANNUAL CASH FLOW	0.4	0.5	0.6	0.4	0.5	0.6	0.1	0.1	0.1	0.8	1.1	1.4
PRESENT VALUE	3.0	4.0	5.0	3.2	4.3	5.4	0.7	1.0	1.2	6.9	9.2	11.6

TABLE 14. AN ESTIMATE OF THE POTENTIAL COST TO THE AVERAGE BROADCAST STATION OF GUIDELINES LIMITING PUBLIC EXPOSURE TO RADIOFREQUENCY RADIATION FROM AM, FM, VHF-TV, AND UHF-TV BROADCAST SOURCES IS GIVEN FOR 3 COST LEVELS. THE AVERAGE ANNUAL CASH FLOW (CURRENT YEAR DOLLAR) COST, THE AVERAGE PRESENT (CONSTANT DOLLAR) VALUE OF THE NET AFTER TAX COST AND THE MAXIMUM AND AVERAGE PERCENT REDUCTION IN NET PROFIT ARE SHOWN FOR COMPLIANCE WITH 18 SPECIFIED GUIDANCE LEVELS. IT IS ASSUMED THAT FM STATIONS SELECT ONE OF FIVE COMPLIANCE MEASURES (2 THROUGH 6) AND THAT COMPLIANCE COSTS (ANNUAL NET CASH FLOW) ARE SPREAD EVENLY AMONG FIVE ANNUAL COHORTS OF STATIONS. NUMBERS ARE IN THOUSANDS OF DOLLARS. MICROWATTS PER SQ. CM IS ABBREVIATED UW/CM^2; VOLTS PER METER, V/M.

	FM			AM			TV		
GUIDANCE LEVEL	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
1.		1. UW/CM^2			10. V/M			1. UW/CM^2	
AVG ANNUAL CASH FLOW	3.8	6.7	9.7	0.9	1.4	1.8	26.0	43.4	67.8
AVERAGE PRESENT VALUE	16.2	28.2	40.6	4.0	5.9	7.9	109.4	182.4	285.3
MAX PROFIT DROP (%)	7.0	11.7	16.4	2.7	3.9	5.1	3.2	5.4	8.4
AVG PROFIT DROP (%)	4.0	7.0	10.1	1.2	1.8	2.4	2.0	3.3	5.2
2.		10. UW/CM^2			32. V/M			10. UW/CM^2	
AVG ANNUAL CASH FLOW	1.9	4.2	6.0	0.5	0.7	0.9	20.1	31.5	38.2
AVERAGE PRESENT VALUE	8.1	17.7	25.1	2.0	2.9	3.9	84.5	132.7	160.8
MAX PROFIT DROP (%)	3.8	7.7	10.7	1.7	2.4	3.1	2.5	3.9	4.8
AVG PROFIT DROP (%)	2.0	4.4	6.2	0.6	0.9	1.1	1.5	2.4	2.9
3.		20. UW/CM^2			45. V/M			20. UW/CM^2	
AVG ANNUAL CASH FLOW	1.9	4.1	5.7	0.4	0.6	0.7	17.3	25.3	29.5
AVERAGE PRESENT VALUE	8.0	17.3	24.3	1.8	2.5	3.3	72.6	106.5	124.4
MAX PROFIT DROP (%)	3.8	7.6	10.5	1.6	2.2	2.9	2.2	3.2	3.7
AVG PROFIT DROP (%)	2.0	4.3	6.0	0.5	0.7	1.0	1.3	1.9	2.3
4.		50. UW/CM^2			71. V/M			50. UW/CM^2	
AVG ANNUAL CASH FLOW	1.8	3.9	5.4	0.3	0.5	0.6	12.9	19.0	21.8
AVERAGE PRESENT VALUE	7.7	16.5	22.9	1.5	2.1	2.8	54.5	80.1	91.8
MAX PROFIT DROP (%)	3.6	7.3	10.0	1.5	2.0	2.6	1.6	2.4	2.8
AVG PROFIT DROP (%)	1.9	4.1	5.7	0.4	0.6	0.8	1.0	1.5	1.7

TABLE 14. (CONTINUED)

GUIDANCE LEVEL	FM LOW	FM MED	FM HIGH	AM LOW	AM MED	AM HIGH	TV LOW	TV MED	TV HIGH
5.		75. UW/CM^2			87. V/M			75. UW/CM^2	
AVG ANNUAL CASH FLOW	1.8	3.9	5.4	0.3	0.5	0.6	11.4	16.3	18.3
AVERAGE PRESENT VALUE	7.6	16.5	22.8	1.4	2.0	2.6	48.1	68.8	77.1
MAX PROFIT DROP (%)	3.6	7.3	9.9	1.4	2.0	2.5	1.4	2.1	2.3
AVG PROFIT DROP (%)	1.9	4.1	5.6	0.4	0.6	0.8	0.9	1.3	1.4
6.		100. UW/CM^2			100. V/M			100. UW/CM^2	
AVG ANNUAL CASH FLOW	1.8	3.8	5.2	0.3	0.4	0.6	10.8	15.1	16.7
AVERAGE PRESENT VALUE	7.5	16.1	22.0	1.4	2.0	2.6	45.6	63.7	70.3
MAX PROFIT DROP (%)	3.6	7.2	9.7	1.4	2.0	2.5	1.4	1.9	2.1
AVG PROFIT DROP (%)	1.8	4.0	5.4	0.4	0.6	0.8	0.8	1.2	1.3
7.		200. UW/CM^2			141. V/M			200. UW/CM^2	
AVG ANNUAL CASH FLOW	1.7	3.7	5.0	0.3	0.4	0.6	8.0	10.9	12.0
AVERAGE PRESENT VALUE	7.4	15.8	21.4	1.4	2.0	2.6	33.8	45.9	50.6
MAX PROFIT DROP (%)	3.5	7.1	9.5	1.4	2.0	2.5	1.0	1.4	1.5
AVG PROFIT DROP (%)	1.8	3.9	5.3	0.4	0.6	0.7	0.6	0.8	0.9
8.		300. UW/CM^2			173. V/M			300. UW/CM^2	
AVG ANNUAL CASH FLOW	1.7	3.7	4.9	0.3	0.4	0.5	7.3	9.8	10.8
AVERAGE PRESENT VALUE	7.2	15.5	20.9	1.3	1.9	2.4	30.9	41.2	45.5
MAX PROFIT DROP (%)	3.5	7.0	9.3	1.4	1.9	2.4	0.9	1.3	1.4
AVG PROFIT DROP (%)	1.8	3.8	5.2	0.4	0.5	0.7	0.6	0.7	0.8

TABLE 14. (CONTINUED)

GUIDANCE LEVEL	FM LOW	FM MED	FM HIGH	AM LOW	AM MED	AM HIGH	TV LOW	TV MED	TV HIGH
9.		400. UW/CM^2			200. V/M			400. UW/CM^2	
AVG ANNUAL CASH FLOW	1.7	3.6	4.8	0.3	0.4	0.5	7.3	9.7	10.7
AVERAGE PRESENT VALUE	7.1	15.2	20.5	1.3	1.9	2.4	30.7	41.0	45.2
MAX PROFIT DROP (%)	3.4	6.8	9.1	1.4	1.9	2.4	0.9	1.3	1.4
AVG PROFIT DROP (%)	1.7	3.8	5.1	0.4	0.5	0.7	0.6	0.7	0.8
10.		500. UW/CM^2			224. V/M			500. UW/CM^2	
AVG ANNUAL CASH FLOW	1.7	3.6	4.8	0.3	0.4	0.5	7.2	9.7	10.6
AVERAGE PRESENT VALUE	7.1	15.2	20.4	1.3	1.9	2.4	30.5	40.7	44.9
MAX PROFIT DROP (%)	3.4	6.8	9.1	1.4	1.9	2.4	0.9	1.2	1.4
AVG PROFIT DROP (%)	1.7	3.7	5.0	0.4	0.5	0.7	0.6	0.7	0.8
11.		600. UW/CM^2			245. V/M			600. UW/CM^2	
AVG ANNUAL CASH FLOW	1.6	3.5	4.7	0.3	0.4	0.5	5.5	7.3	8.0
AVERAGE PRESENT VALUE	6.9	14.9	20.0	1.3	1.9	2.4	23.1	30.8	34.0
MAX PROFIT DROP (%)	3.3	6.7	8.9	1.4	1.9	2.4	0.7	1.0	1.1
AVG PROFIT DROP (%)	1.7	3.7	4.9	0.4	0.5	0.7	0.4	0.6	0.6
12.		700. UW/CM^2			265. V/M			700. UW/CM^2	
AVG ANNUAL CASH FLOW	1.6	3.4	4.5	0.3	0.4	0.5	5.5	7.3	8.0
AVERAGE PRESENT VALUE	6.7	14.3	19.3	1.3	1.9	2.4	23.1	30.8	34.0
MAX PROFIT DROP (%)	3.3	6.5	8.7	1.4	1.9	2.4	0 7	1.0	1.1
AVG PROFIT DROP (%)	1.6	3.5	4.8	0.4	0.5	0.7	0.4	0.6	0.6

TABLE 14. (CONTINUED)

GUIDANCE LEVEL	FM LOW	FM MED	FM HIGH	AM LOW	AM MED	AM HIGH	TV LOW	TV MED	TV HIGH
13.		800. UW/CM^2			282. V/M			800. UW/CM^2	
AVG ANNUAL CASH FLOW	1.5	3.3	4.5	0.3	0.4	0.5	5.5	7.3	8.0
AVERAGE PRESENT VALUE	6.6	14.1	18.9	1.3	1.9	2.4	23.1	30.8	34.0
MAX PROFIT DROP (%)	3.2	6.4	8.5	1.4	1.9	2.4	0.7	1.0	1.1
AVG PROFIT DROP (%)	1.6	3.5	4.7	0.4	0.5	0.7	0.4	0.6	0.6
14.		900. UW/CM^2			300. V/M			900. UW/CM^2	
AVG ANNUAL CASH FLOW	1.5	3.3	4.4	0.3	0.4	0.5	5.5	7.3	8.0
AVERAGE PRESENT VALUE	6.5	14.0	18.8	1.3	1.9	2.4	23.1	30.8	34.0
MAX PROFIT DROP (%)	3.2	6.3	8.5	1.4	1.9	2.4	0.7	1.0	1.1
AVG PROFIT DROP (%)	1.6	3.4	4.6	0.4	0.5	0.7	0.4	0.6	0.6
15.		1000. UW/CM^2			316. V/M			1000. UW/CM^2	
AVG ANNUAL CASH FLOW	1.5	3.2	4.3	0.3	0.4	0.5	5.5	7.3	8.0
AVERAGE PRESENT VALUE	6.4	13.6	18.3	1.3	1.9	2.4	23.1	30.8	34.0
MAX PROFIT DROP (%)	3.1	6.2	8.3	1.4	1.9	2.4	0.7	1.0	1.1
AVG PROFIT DROP (%)	1.6	3.4	4.5	0.4	0.5	0.7	0.4	0.6	0.6
16.		2000. UW/CM^2			447. V/M			2000. UW/CM^2	
AVG ANNUAL CASH FLOW	1.4	2.9	3.9	0.3	0.4	0.5	0.1	0.2	0.2
AVERAGE PRESENT VALUE	5.8	12.3	16.5	1.3	1.8	2.4	0.7	0.9	1.1
MAX PROFIT DROP (%)	2.9	5.7	7.6	1.4	1.9	2.4	0.1	0.1	0.1
AVG PROFIT DROP (%)	1.4	3.0	4.1	0.4	0.5	0.7	0.0	0.0	0.0

TABLE 14. (CONTINUED)

GUIDANCE LEVEL	FM LOW	FM MED	FM HIGH	AM LOW	AM MED	AM HIGH	TV LOW	TV MED	TV HIGH
17.		5000. UW/CM^2			708. V/M			5000. UW/CM^2	
AVG ANNUAL CASH FLOW	1.2	2.4	3.3	0.3	0.4	0.5	0.1	0.2	0.2
AVERAGE PRESENT VALUE	5.0	10.4	14.0	1.3	1.8	2.3	0.7	0.9	1.1
MAX PROFIT DROP (%)	2.6	4.9	6.6	1.4	1.9	2.4	0.1	0.1	0.1
AVG PROFIT DROP (%)	1.2	2.6	3.4	0.4	0.5	0.7	0.0	0.0	0.0
18.		10000. UW/CM^2			1000. V/M			10000. UW/CM^2	
AVG ANNUAL CASH FLOW	1.1	2.3	3.2	0.3	0.4	0.5	0.1	0.2	0.2
AVERAGE PRESENT VALUE	4.8	10.0	13.5	1.3	1.8	2.3	0.7	0.9	1.1
MAX PROFIT DROP (%)	2.5	4.8	6.3	1.4	1.9	2.4	0.1	0.1	0.1
AVG PROFIT DROP (%)	1.2	2.4	3.3	0.4	0.5	0.7	0.0	0.0	0.0

TABLE 15. THE NUMBER OF FM STATIONS REQUIRING MEASURES TO COMPLY WITH GUIDELINES LIMITING PUBLIC EXPOSURE TO RADIOFREQUENCY RADIATION IS GIVEN FOR 18 SPECIFIED GUIDANCE LEVELS. IT IS ASSUMED THAT STATIONS SELECT ONE OF FIVE COMPLIANCE MEASURES (2 THROUGH 6).

GUIDANCE LEVEL		FIX1	FIX2	FIX3	FIX4	FIX5	FIX6	SUB-TOTAL*	TOTAL**
1. 1 MICROWATT PER SQ. CM									
LOW COST ANALYSIS	SFMT	0	637	1592	129	776	129	3263	
	MFMT	0	14	120	32	192	32	390	3653
MEDIUM COST ANALYSIS	SFMT	0	637	1592	258	517	258	3262	
	MFMT	0	14	120	64	128	64	390	3652
HIGH COST ANALYSIS	SFMT	0	637	1592	388	258	388	3263	
	MFMT	0	14	120	96	64	96	390	3653
2. 10 MICROWATT PER SQ. CM***									
LOW COST ANALYSIS	SFMT	0	1052	1519	25	153	25	2774	
	MFMT	0	59	140	15	91	15	320	3094
MEDIUM COST ANALYSIS	SFMT	0	1052	1519	51	102	51	2775	
	MFMT	0	59	140	30	61	30	320	3095
HIGH COST ANALYSIS	SFMT	0	1052	1519	76	51	76	2774	
	MFMT	0	59	140	45	30	45	319	3093
3. 20 MICROWATT PER SQ. CM									
LOW COST ANALYSIS	SFMT	0	1021	1028	12	76	12	2149	
	MFMT	0	65	115	12	75	12	279	2428
MEDIUM COST ANALYSIS	SFMT	0	1021	1028	25	51	25	2150	
	MFMT	0	65	115	25	50	25	280	2430
HIGH COST ANALYSIS	SFMT	0	1021	1028	38	25	38	2150	
	MFMT	0	65	115	37	25	37	279	2429

*TOTAL NUMBER OF STATIONS REQUIRING A FIX AT THE SPECIFIED GUIDANCE LEVEL
SFMT=SINGLE FM TOWER, MFMT=MULTIPLE FM TOWER
**FACTORS ASSIGNING STATIONS AMONG FIXES 4,5 AND 6 CREATE ROUNDING ERRORS.
***THE NUMBER OF STATIONS REQUIRING FIX 2 INCREASES AT GUIDANCE LEVEL 2 BECAUSE GUIDANCE LEVEL 1 REQUIRES MORE STATIONS TO ADOPT MORE COMPLEX MITIGATION MEASURES.

TABLE 15. (CONTINUED)

GUIDANCE LEVEL		FIX1	FIX2	FIX3	FIX4	FIX5	FIX6	SUB-TOTAL*	TOTAL**
4. 50 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	818	500	4	26	4	1352	
ANALYSIS	MFMT	0	83	86	7	42	7	225	1577
MEDIUM COST	SFMT	0	818	500	8	17	8	1351	
ANALYSIS	MFMT	0	83	86	14	28	14	225	1576
HIGH COST	SFMT	0	818	500	13	8	13	1352	
ANALYSIS	MFMT	0	83	86	21	14	21	225	1577
5. 75 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	733	345	3	18	3	1102	
ANALYSIS	MFMT	0	62	86	5	32	5	190	1292
MEDIUM COST	SFMT	0	733	345	6	12	6	1102	
ANALYSIS	MFMT	0	62	86	10	21	10	189	1291
HIGH COST	SFMT	0	733	345	9	6	9	1102	
ANALYSIS	MFMT	0	62	86	16	10	16	190	1292
6. 100 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	686	286	1	10	1	984	
ANALYSIS	MFMT	0	55	104	2	13	2	176	1160
MEDIUM COST	SFMT	0	686	286	3	6	3	984	
ANALYSIS	MFMT	0	55	104	4	8	4	175	1159
HIGH COST	SFMT	0	686	286	5	3	5	985	
ANALYSIS	MFMT	0	55	104	6	4	6	175	1160

*TOTAL NUMBER OF STATIONS REQUIRING A FIX AT THE SPECIFIED GUIDANCE LEVEL
SFMT=SINGLE FM TOWER, MFMT=MULTIPLE FM TOWER
**FACTORS ASSIGNING STATIONS AMONG FIXES 4,5 AND 6 CREATE ROUNDING ERRORS.

TABLE 15 . (CONTINUED)

GUIDANCE LEVEL		FIX1	FIX2	FIX3	FIX4	FIX5	FIX6	SUB-TOTAL*	TOTAL**
7. 200 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	460	166	0	1	0	627	
ANALYSIS	MFMT	0	43	77	0	5	0	125	752
MEDIUM COST	SFMT	0	460	166	0	1	0	627	
ANALYSIS	MFMT	0	43	77	1	3	1	125	752
HIGH COST	SFMT	0	460	166	0	0	0	626	
ANALYSIS	MFMT	0	43	77	2	1	2	125	751
8. 300 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	340	108	0	0	0	448	
ANALYSIS	MFMT	0	43	69	0	0	0	112	560
MEDIUM COST	SFMT	0	340	108	0	0	0	448	
ANALYSIS	MFMT	0	43	69	0	0	0	112	560
HIGH COST	SFMT	0	340	108	0	0	0	448	
ANALYSIS	MFMT	0	43	69	0	0	0	112	560
9. 400 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	233	80	0	0	0	313	
ANALYSIS	MFMT	0	42	58	0	0	0	100	413
MEDIUM COST	SFMT	0	233	80	0	0	0	313	
ANALYSIS	MFMT	0	42	58	0	0	0	100	413
HIGH COST	SFMT	0	233	80	0	0	0	313	
ANALYSIS	MFMT	0	42	58	0	0	0	100	413

*TOTAL NUMBER OF STATIONS REQUIRING A FIX AT THE SPECIFIED GUIDANCE LEVEL
SFMT=SINGLE FM TOWER, MFMT=MULTIPLE FM TOWER
**FACTORS ASSIGNING STATIONS AMONG FIXES 4,5 AND 6 CREATE ROUNDING ERRORS.

TABLE 15 . (CONTINUED)

GUIDANCE LEVEL		FIX1	FIX2	FIX3	FIX4	FIX5	FIX6	SUB-TOTAL*	TOTAL**
10. 500 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	188	64	0	0	0	252	
ANALYSIS	MFMT	0	43	50	0	0	0	93	345
MEDIUM COST	SFMT	0	188	64	0	0	0	252	
ANALYSIS	MFMT	0	43	50	0	0	0	93	345
HIGH COST	SFMT	0	188	64	0	0	0	252	
ANALYSIS	MFMT	0	43	50	0	0	0	93	345
11. 600 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	162	48	0	0	0	210	
ANALYSIS	MFMT	0	39	42	0	0	0	81	291
MEDIUM COST	SFMT	0	162	48	0	0	0	210	
ANALYSIS	MFMT	0	39	42	0	0	0	81	291
HIGH COST	SFMT	0	162	48	0	0	0	210	
ANALYSIS	MFMT	0	39	42	0	0	0	81	291
12. 700 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	134	42	0	0	0	176	
ANALYSIS	MFMT	0	38	31	0	0	0	69	245
MEDIUM COST	SFMT	0	134	42	0	0	0	176	
ANALYSIS	MFMT	0	38	31	0	0	0	69	245
HIGH COST	SFMT	0	134	42	0	0	0	176	
ANALYSIS	MFMT	0	38	31	0	0	0	69	245

*TOTAL NUMBER OF STATIONS REQUIRING A FIX AT THE SPECIFIED GUIDANCE LEVEL
SFMT=SINGLE FM TOWER, MFMT=MULTIPLE FM TOWER
**FACTORS ASSIGNING STATIONS AMONG FIXES 4,5 AND 6 CREATE ROUNDING ERRORS.

TABLE 15 . (CONTINUED)

GUIDANCE LEVEL		FIX1	FIX2	FIX3	FIX4	FIX5	FIX6	SUB-TOTAL*	TOTAL**
13. 800 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	123	35	0	0	0	158	
ANALYSIS	MFMT	0	39	29	0	0	0	68	226
MEDIUM COST	SFMT	0	123	35	0	0	0	158	
ANALYSIS	MFMT	0	39	29	0	0	0	68	226
HIGH COST	SFMT	0	123	35	0	0	0	158	
ANALYSIS	MFMT	0	39	29	0	0	0	68	226
14. 900 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	107	31	0	0	0	138	
ANALYSIS	MFMT	0	38	25	0	0	0	63	201
MEDIUM COST	SFMT	0	107	31	0	0	0	138	
ANALYSIS	MFMT	0	38	25	0	0	0	63	201
HIGH COST	SFMT	0	107	31	0	0	0	138	
ANALYSIS	MFMT	0	38	25	0	0	0	63	201
15. 1000 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	105	24	0	0	0	129	
ANALYSIS	MFMT	0	39	20	0	0	0	59	188
MEDIUM COST	SFMT	0	105	24	0	0	0	129	
ANALYSIS	MFMT	0	39	20	0	0	0	59	188
HIGH COST	SFMT	0	105	24	0	0	0	129	
ANALYSIS	MFMT	0	39	20	0	0	0	59	188

*TOTAL NUMBER OF STATIONS REQUIRING A FIX AT THE SPECIFIED GUIDANCE LEVEL
SFMT=SINGLE FM TOWER, MFMT=MULTIPLE FM TOWER
**FACTORS ASSIGNING STATIONS AMONG FIXES 4,5 AND 6 CREATE ROUNDING ERRORS.

TABLE 15. (CONTINUED)

GUIDANCE LEVEL		FIX1	FIX2	FIX3	FIX4	FIX5	FIX6	SUB-TOTAL*	TOTAL**
16. 2000 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	56	10	0	0	0	66	
ANALYSIS	MFMT	0	22	6	0	0	0	28	94
MEDIUM COST	SFMT	0	56	10	0	0	0	66	
ANALYSIS	MFMT	0	22	6	0	0	0	28	94
HIGH COST	SFMT	0	56	10	0	0	0	66	
ANALYSIS	MFMT	0	22	6	0	0	0	28	94
17. 5000 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	16	0	0	0	0	16	
ANALYSIS	MFMT	0	8	0	0	0	0	8	24
MEDIUM COST	SFMT	0	16	0	0	0	0	16	
ANALYSIS	MFMT	0	8	0	0	0	0	8	24
HIGH COST	SFMT	0	16	0	0	0	0	16	
ANALYSIS	MFMT	0	8	0	0	0	0	8	24
18. 10000 MICROWATT PER SQ. CM									
LOW COST	SFMT	0	3	0	0	0	0	3	
ANALYSIS	MFMT	0	0	0	0	0	0	0	3
MEDIUM COST	SFMT	0	3	0	0	0	0	3	
ANALYSIS	MFMT	0	0	0	0	0	0	0	3
HIGH COST	SFMT	0	3	0	0	0	0	3	
ANALYSIS	MFMT	0	0	0	0	0	0	0	3

*TOTAL NUMBER OF STATIONS REQUIRING A FIX AT THE SPECIFIED GUIDANCE LEVEL
SFMT=SINGLE FM TOWER, MFMT=MULTIPLE FM TOWER
**FACTORS ASSIGNING STATIONS AMONG FIXES 4,5 AND 6 CREATE ROUNDING ERRORS.

TABLE 16. THE NUMBER OF AM BROADCAST STATIONS REQUIRING MEASURES TO COMPLY WITH GUIDELINES LIMITING PUBLIC EXPOSURE TO RADIOFREQUENCY RADIATION IS GIVEN FOR 18 SPECIFIED GUIDANCE LEVELS AT THREE COST LEVELS. ACTUAL NUMBER OF STATIONS ESTIMATED TO REQUIRE MITIGATION MEASURE ADJUSTED BY FACTORS GIVEN IN TABLE 5.

GUIDANCE LEVEL		LOW COST	MEDIUM COST	HIGH COST
1	10.00 V/M	2311	3081	3928
2	31.62 V/M	2311	3081	3928
3	44.67 V/M	2310	3080	3927
4	70.79 V/M	2273	3030	3864
5	86.60 V/M	2246	2995	3819
6	100.00 V/M	2095	2793	3562
7	141.25 V/M	1856	2475	3156
8	173.18 V/M	1700	2266	2890
9	200.00 V/M	1690	2253	2873
10	223.87 V/M	844	1125	1435
11	244.91 V/M	831	1107	1412
12	264.55 V/M	776	1034	1319
13	281.84 V/M	773	1031	1314
14	300.00 V/M	773	1030	1314
15	316.23 V/M	762	1015	1295
16	446.68 V/M	710	946	1207
17	707.95 V/M	185	247	315
18	1000.00 V/M	87	116	148

TABLE 17. THE NUMBER OF TV BROADCAST STATIONS AFFECTED BY GUIDELINES LIMITING PUBLIC EXPOSURE TO RADIOFREQUENCY RADIATION IS GIVEN FOR 18 SPECIFIED GUIDANCE LEVELS.

	GUIDANCE LEVEL	
1	1 MICROWATTS PER SQ. CM	819
2	10 MICROWATTS PER SQ. CM	246
3	20 MICROWATTS PER SQ. CM	183
4	50 MICROWATTS PER SQ. CM	102
5	75 MICROWATTS PER SQ. CM	73
6	100 MICROWATTS PER SQ. CM	60
7	200 MICROWATTS PER SQ. CM	30
8	300 MICROWATTS PER SQ. CM	19
9	400 MICROWATTS PER SQ. CM	13
10	500 MICROWATTS PER SQ. CM	10
11	600 MICROWATTS PER SQ. CM	5
12	700 MICROWATTS PER SQ. CM	4
13	800 MICROWATTS PER SQ. CM	3
14	900 MICROWATTS PER SQ. CM	3
15	1000 MICROWATTS PER SQ. CM	2
16	2000 MICROWATTS PER SQ. CM	0
17	5000 MICROWATTS PER SQ. CM	0
18	10000 MICROWATTS PER SQ. CM	0

REFERENCES

1. The President of the United States, "Executive Order 12291, Federal Regulation," Federal Register 46, 13193-13198 (February 19, 1981).

2. Office of Management and Budget, "Interim Regulatory Impact Analysis Guidance," Executive Office of the President, Washington, DC (June 12, 1981).

3. U.S. Environmental Protection Agency, Guidelines for Performing Regulatory Impact Analyses (Draft), Washington, DC (August 1982).

4. Gailey, P.C., and R.A. Tell, An Engineering Assessment of the Potential Impact of Federal Radiation Protection Guidance on the AM, FM, and TV Broadcast Services, U.S. Environmental Protection Agency, Washington, DC (in press).

5. Steneck, N.H., H.J. Cook, A.J. Vander and G.L. Kane, "The Origins of U.S. Safety Standards for Microwave Radiation," Science 208, 1230-1237 (June 13, 1980).

6. American National Standards Institute, "American National Standard C-95.1- (1982): Safety levels with Respect to Radiofrequency Electromagnetic Field (300 kHz to 100 Ghz)" (Draft), Board of Standards Review, New York (1982).

7. National Environmental Policy Act of 1969, Section 102 (2)(B), 42 U.S.C. Section 4332 (2)(B) (1976).

8. U.S. Federal Communications Commission, "Notice of Inquiry," Federal Register 44, 37003 (June 25, 1979).

9. U.S. Federal Communications Commission, "Advance Notice of Proposed Rulemaking," Federal Register 47, 8214 (February 25, 1982).

10. U.S. Environmental Protection Agency, "Advance Notice of Proposed Rulemaking," Federal Register 47, 57338 (December 23, 1982).

11. U.S. Environmental Protection Agency, "Federal Radiation Protection Guidance for Public Exposure to Radiofrequency Radiation," Office of Radiation Programs, Washington, DC (in agency review).

12. U.S. Environmental Protection Agency, Biological Effects of Radiofrequency Radiation, J.A. Elder and D.F. Cahill, Eds., Health Effects Research Laboratory, Research Triangle Park, North Carolina, EPA-600/8-83-026F (September 1984).

13. Hankin, N.N., The Radiofrequency Radiation Environment; Environmental Exposure Levels and RF Emitting Sources, U.S. Environmental Protection Agency, Washington, D.C., (in press) 1985.

14. Steneck, N.H., H.J. Cook, A.J. Vander and G.L. Kane, "The Origins of U.S. Safety Standards for Microwave Radiation," Science 298, 1230 (1980).

15. Steneck, N.H., H.J. Cook, A.J. Vander and G.L. Kane, "The Origins of U.S. Safety Standards for Microwave Radiation," Science 298, 1231 (1980).

16. Cahill, D.F., "A Suggested Limit for Population Exposure to Radiofrequency Radiation," Health Physics 45, 110 (1983).

17. Microwave News, II(1), 6 (January-February 1982); II (7), 3-5 (September 1982); II (9), 4 (November 1982); III (2), 5 (March 1983); III (3), 3-4 (April 1983).

18. Microwave News, II(9), 2,3 (November 1982); II(10), 1-4, 11 (December 1982); III (1), 4,5,7 (January-February 1983).

19. Microwave News, II(2), 1 (March 1982); II(6), 7 (August 1982); II(8), 7 (October 1982); III(4), 4 (May 1983); III(5), 3 (June 1983); III(7), 5 (September 1983).

20. U.S. Federal Communications Commission, 47th Annual Report, Fiscal Year 1981, Washington, DC (1981).

21. de Sola Pool, I., "Tracking the Flow of Information," Science 221, 609-613 (1983).

22. Sassone, P.G., and W.P. Schaffer, Cost-Benefit Analysis: A Handbook (Academic Press, Inc., New York, 1978), pp. 3-4.

23. Sassone, P.G., and W.P. Schaffer, Cost-Benefit Analysis: A Handbook (Academic Press, Inc., New York, 1978), p. 4.

24. Pearce, D.W., and C.A. Nash, The Social Appraisal of Projects; A Text in Cost-Benefit Analysis (John Wiley and Sons, New York, 1981), p. 1.

25. Baram, M.S., "Cost-Benefit Analysis: An Inadequate Basis for Health, Safety, and Environmental Regulatory Decisionmaking," Ecology Law Quarterly 8, 474 (Footnote 1) (1979).

26. Baram, M.S., "Cost-Benefit Analysis: An Inadequate Basis for Health, Safety, and Environmental Regulatory Decisionmaking," Ecology Law Quarterly 8, 479 (Footnote 21) (1979).

27. The President of the United States, "Executive Order 12044, Improving Government Regulations," 43 FR 12661.

28. The President of the United States, "Executive Order 12291," Section 2(b); Section 2 (c); Section 2 (e) 46 FR 13193.

29. The President of the United States, "Executive Order 12291," Section 1(b) (1-3) 46 FR 13193.

30. The President of the United States, "Executive Order 12291," Section 3(d) (1-4) 46 FR 13193.

31. Office of Management and Budget, "Interim Regulatory Impact Analysis Guidance," Executive Office of the President, Washington, DC (June 12, 1981), pp. 2-4.

32. U.S. Environmental Protection Agency, Guidelines for Performing Regulatory Report Analysis (Draft), Washington, DC (August 1982).

33. DeMuth, C.C., "The Regulatory Budget," Regulation 4(1), 29-44 (March/April, 1980).

34. Baram, M.S., Alternatives to Regulation (Lexington Books, Lexington, 1982).

35. Kelman, S., "Cost-Benefit Analysis: An Ethical Critique," Regulation 5(1), 33-40 (January/February 1981).

36. U.S. Environmental Protection Agency, Checklist of Regulatory Alternatives, Office of Planning and Management, Washington, DC (July 1980).

37. Baram, M.S., "Cost-Benefit Analysis: An Inadequate Basis for Health, Safety, and Environmental Regulatory Decisionmaking," Ecology Law Quarterly 8, 526 (1979).

38. Janes, D.E., Jr., "The EPA Environmental Radio-Frequency Radiation Program," Electromagnetic Interference Workshop, National Bureau of Standards, Gaithersburg, Maryland (July 12-13, 1977).

39. Tell, R.A., "Broadcast Radiation: How Safe is Safe?," IEEE Spectrum 9(8), 43-51 (August 1972).

40. Tell, R.A., and E.D. Mantiply, "Population Exposure to VHF and UHF Broadcast Radiation in the United States," Proceedings of the IEEE, 68(1), 6-12 (January 1980).

41. Athey, T.W., R.A. Tell, N.N. Hankin, D.L. Lambdin, E.D. Mantiply, and D.E. Janes, Radiofrequency Radiation Levels and Population Exposure in Urban Areas of the Eastern United States, U.S. Environmental Protection Agency, Washington, DC, EPA-520/2-77-008 (1978).

42. Tell, R.A., D.L. Lambdin, R.E. Brown, and E.D. Mantiply, Electric Field Strengths in the Near Vicinity of FM Radio Broadcast Antennas, IEEE Broadcast Symposium, Washington, DC (September 21, 1979).

43. Hankin, N.N., Radiation Characteristics of Traffic Radar Systems, U.S. Environmental Protection Agency, Washington, DC, ORP/EAD-76-1 (March 1976).

44. Tell, R.A., An Analysis of Radar Exposure in the San Francisco Area, U.S. Environmental Protection Agency, Washington, DC, ORP/EAD-77-3 (March 1977).

45. Tell, R.A., and J.C. Nelson, "Microwave Hazard Measurements Near Various Aircraft Radars," Radiation Data and Reports 15, 161-179 (1974).

46. Tell, R.A., and N.N. Hankin, Measurement of Radiofrequency Field Industry in Buildings with Close Proximity to Broadcast Stations, U.S. Environmental Protection Agency, Washington, DC, ORP/EAD-78-3 (August 1978).

47. Tell, R.A., Near-Field Radiation Properties of Simple Linear Antennas with Applications to Radiofrequency Hazards and Broadcasting, U.S. Environmental Protection Agency, Washington, DC, ORP/EAD-78-4 (June 1978).

48. U.S. Environmental Protection Agency, Office of Radiation Programs, Las Vegas, NV, personal communication (1983).

49. Burke, G.J., and A.J. Poggio, Numerical Electromagnetic Code - Method of Moments, Prepared for the Naval Ocean Systems Command, Lawrence Livermore National Laboratory, Livermore, CA, UCID-18834 (January 81), Vols. 1 and 2.

50. Adler, R.W., and S. Lamont, Numerical Modeling Study of Gain and Downward Radiation from Selected FM and VHF-TV Broadcast Antenna Systems, AGL, Incorporated, Pacific Grove, CA (March 1984).

51. Jules Cohen and Associates, Washington, DC, personal communication (February 22, 1983).

52. Hammett and Edison, Incorporated, San Francisco, CA, personal communication (March 18, 1983).

53. Hammett and Edison, Incorporated, San Francisco, CA, personal communication (April 18, 1983).

54. Hammett and Edison, Incorporated, San Francisco, CA, personal communication (March 22, 1983).

55. Neufeld, Jeff, Lawrence Livermore National Laboratory, Livermore, CA, personnel communication.

56. Hammett and Edison, Incorporated, San Francisco, CA, personal communication (May 27, 1983).

57. Barish, N.N., Economic Analysis for Engineering and Managerial Decision-Making (McGraw-Hill Book Company, NY, 1962).

58. Coller, C.A. and W.B. Ledbetter, Engineering Cost Analysis (Harper-Row, NY, 1982).

59. Grant, E.L., W.G. Ireson and R.S. Leavenworth, Principles of Engineering Economy (John Wiley & Sons, New York, 1976).

60. Mishan, E., Cost-Benefit Analysis: An Introduction (Praeger, New York, 1971).

61. Newman, D.G., Engineering Economic Analysis (Engineering Press, San Jose, CA, 1976).

62. Riggs, J.L., Engineering Economics (McGraw-Hill Book Co., New York, 1977).

63. Smith, G.W., Engineering Economy: Analysis of Capital Expenditures, Third Edition (The Iowa State University Press, Ames, IA, 1979).

64. White, J.A., M.H. Agee and K.E. Case, Principles of Engineering Economic Analysis (John Wiley & Sons, New York, 1977).

65. Anderson, L.G. and R.F. Settle, Benefit-Cost Analysis: A Practical Guide (Lexington Books, Lexington, KY, 1979), pp. 92.

66. Bunger, B., Environmental Protection Agency, Washington DC, personal communication (December 17, 1982).

67. Niswonger, C.R., and P.E. Fess, Accounting Principles, 12th Ed. (South-Western Publishing Co., Cincinnati, OH, 1977).

68. Meigs, W.B., C.E. Johnson, and R.F. Meigs, Accounting: The Basis for Business Decisions, Fourth Ed. (McGraw-Hill Book Co., New York, 1977).

69. Weston, J.F., and E.F. Bringham, Essentials of Managerial Finance, Fourth Ed. (Holt, Rinehart, and Winston, Hinsdale, IL, 1971).

70. Horngren, C.T., Cost Accounting; A Managerial Emphasis (Prentice-Hall, Englewood Cliffs, NJ, 1977).

71. Commerce Clearing House, Inc., 1983 U.S. Master Tax Code (Chicago, IL, 1982), p. 419.

72. U.S. Federal Communications Commission, 47th Annual Report, Fiscal Year 1981, Washington, DC (1981).

73. Commerce Clearing House, Inc., 1983 U.S. Master Tax Code (Chicago, IL, 1982), p. 21.