10 February 1983
(Revised 25 April 1983)

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A STUDY OF FUTURE DIRECTIONS FOR THE VOICE OF AMERICA IN THE CHANGING WORLD OF INTERNATIONAL BROADCASTING

John E. Ward

Ithiel De Sola Pool

Richard J. Solomon

MIT Research Program on Communications Policy

Laboratory for Information and Decision Systems
MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASSACHUSETTS 02139

VOA - FINAL REPORT

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Massachusetts Institute of Technology
Cambridge, MA 02139

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ABSTRACT

This document presents the findings of a study of the present international broadcast operations of the Voice of America, and makes recommendations for actions felt necessary for the VOA to maintain its present stature among world broadcasters for the coming decades. Particular topics discussed are the international transmitter power race, possibilities for signal enhancement by improved antenna technology and control, jamming, issues to be considered in planning for satellite direct broadcast radio services, other new-technology means of reaching at least part of the worldwide audience, and the possibilities for cost savings through automation of relay station equipment and computer aids for headquarters operations.

FOREWORD

The study under this contract was carried out over the period 1 March 1982 though 31 January 1983, and the Final Report, dated 10 February 1983, was submitted to VOA in fulfillment of the contract. At the time, however, not all the reviewers to whom the report had been sent had had time to return their comments. VOA agreed that a revised Final Report should be prepared if it was deemed by M.I.T. that the remaining comments so warranted.

This 25 April 1983 revision incorporates a number of corrections, rewordings, and minor additions made as a result of those reviewer comments; also the opportunity was taken to rewrite and expand two sections pertaining to receiver technology for improved clarity of the suggestions presented (Sections II-B and III-B-3). Recommendation No. 16 has been added to the Summary.

An Executive Summary, bound separately, has also been prepared to present the key findings of the study in a less formidable document for those not needing to know all the details.

INTRODUCTION

As the number of countries doing short wave broadcasting has grown to 123 today, and as more and more of them build superpower transmitters, it becomes ever harder for the Voice of America to reach its worldwide audience through the crowded airwaves. The problem is compounded by Soviet jamming and by the fact that much of the American transmission plant was built in the 1950's and is technologically, and even physically obsolete.

In response to these problems numerous proposals have been made during the past two decades for the U.S. Government to invest in upgrading the present transmitter facilities and building new ones, using modern technology. The capital investment needed to give America an effective Voice for the coming two or more critical decades, while small in the total national security picture, will be hundreds of millions of dollars.

Conscious of this problem, the Research Program on Communications Policy at the Massachusetts Institute of Technology approached the management of the Voice of America in July 1981, and suggested that it would be advisable to take an independent outside view of the proposals coming before VOA to assess whether they are moving technically and at reasonable costs in the right direction. That was the origin of this study.

We make no pretense in a small 6 man-month study to have examined engineering plans for specific sites or details of alternatives. We have looked at the basic planning ideas that are now in the pipeline to assess them in the light of the present state of the art of radio communication. In this report we present our conclusions which are largely in concurrence with VOA's present engineering plans, but we do raise a few important questions, some of which can only be answered by detailed engineering and economic studies, and a few of which require decision at the highest levels of U.S. policy making.

While this is primarily a technical study, it has crucial political parameters. A judgment of the kind of transmission facilities that should now be built for the future depends on estimates of who it is that will need to be reached in what parts of the world, how severe the jamming of broadcasts will be, what kind of quality of reception audiences will demand before they will listen, what countries will allow relay transmitters on their territories, and other such non-technical questions.

The study was done by an interdisciplinary team. John E. Ward of the Laboratory for Information and Decision Systems of MIT is an electrical engineer who has worked for many years in the fields of radio and communications systems. Ithiel de Sola Pool is a Professor of Political Science at MIT and Director of the Institute's Research Program on Communications Policy. Prof. Pool has earlier done studies for the Voice of the audience size for foreign broadcasting in the USSR. The third member of the team was Richard Jay Solomon, a specialist in communications and transportation planning, who has recently completed a study of future technologies for radio broadcasting.

The plan for the study included visits and discussions at VOA's two Washington, D.C. headquarters locations, visits to typical U.S. and overseas transmitting sites, and discussions with a number of non-VOA people determined to have expertise in areas pertinent to the study. These were all accomplished, except that only one transmitting site was visited -- the Greenville, North Carolina relay station. A planned trip to Europe to visit VOA, RFE/RL, BBC, Deutsche Welle, and Swiss International Radio transmitting facilities, ITU/IFRB, EBU, and several transmitter manufacturers was cancelled at VOA request.

In the several trips to VOA Headquarters in the period March-May, 1982, we visited the following offices, most more than once, and met with a large number of people:

Associate Director
Deputy Associate Director
Deputy Associate Director, Plans and Programs
Deputy Director, Programs for News and Current Affairs
Director, Office of Engineering and Technical Operations
  Chief, Frequency Division
  Chief, Frequency Utilization Branch
  Chief, Operations Division
  Chief, Operations Management Staff
  Chief, Special Projects Division

These visits provided a good deal of insight on VOA operations and technology, and a large number of pertinent documents were obtained for study.

The procedure for non-VOA interviews was to identify a list of candidates through a process of calling those on a small initial list and getting recommendations for additional people to interview. Some 50 names were obtained in this way. Then a background paper and a list of questions for discussion were prepared and mailed to the persons to be interviewed. These two documents are reproduced in the Appendix. Interviews were mostly by telephone, but some were done in person. Understandably, differences in opinion on some topics were evident in the interviews. Where pertinent, interview information has been identified throughout the report, but not necessarily by source.

SUMMARY

The Voice of America has a world-wide audience of many millions, particularly in lands where access to information is not readily available, and particularly among the politically alert.

This massive audience is a great asset in the conduct of American foreign policy. The Voice's cost/effectiveness exceeds that of most other means of influence.

Present VOA transmission facilities largely date back to the 1950's and 1960's and are becoming obsolete in the increasingly crowded airwaves in which 123 countries are now broadcasting by shortwave. Overseas, VOA has transmitters of 250-kW rating in place. Other countries already have 81 500-kW transmitters in operation with more under construction. What should VOA do?

* * * * * * * * * * * * *

The key points developed in this study are as follows. The rationale for each is developed in later sections.

1. VOA's problem of reaching the listener audience in the increasingly crowded HF spectrum does not seem to be best solved by simply increasing transmitter power everywhere,

which has a major effect on operating expenses. New antenna technology, including narrower, flexibly-directable beams could yield the same or better increases in signal levels at existing power levels in many instances. (See also 2. below.)

2. In addition, VOA should investigate means for real-time, dynamic optimization of transmission parameters, rather than operating almost entirely on the basis of propagation predictions made many months ahead. Backscatter sounding, both of the ionosphere and the target area, seems to show great promise for beam-elevation control, particularly with recent developments in correlation detection for isolating backscatter signals from other received energy. Real-time feedback of signal measurements from monitoring stations should also be investigated as an alternate or an adjunct to backscatter sounding. Power increases should come only after all other signal-delivery optimization means have been fully utilized, and on a case-by-case basis.

3. VOA presently plans and operates its facilities with two fixed "rules of thumb" for minimum delivered signal levels and multiple-frequency, simultaneous transmissions per program per time zone; one rule for unjammed broadcasts, and the other for jammed broadcasts. Such fixed rules, applied worldwide, do not take into account varying reception conditions in the intended listening areas, and there is probably "overkill" in some situations and "underkill" in

others. Examples of reception conditions which vary widely in various parts of the world are background noise level, the number and strengths of interfering signals of other broadcasters, and the effectiveness of jamming, when present. A procedure which could make better use of VOA resources would be to analyze each program delivery situation and allocate transmission facilities to it only as necessary to deliver reliable, listenable signals. Dynamic allocation on a near-real-time basis should be the goal.

4. The VOA seems to lag in the application of computer technology to save time and manpower in many of its critical ongoing operations at its Washington Headquarters. The analyses called for in the preceding paragraphs both require computer modeling. Also, there are two current, intensely manual operations that could benefit greatly from computer aids: the preparation, editing, and inter-office transmission of program text material, and the complex task of preparing new frequency schedules and transmitter assignments four times per year. Computer aids could result in a better product at less cost in both of these areas.

5. The technology of communication is changing rapidly, and the VOA should be preparing to exploit the newer means that could be used to reach certain of its audiences. These include: distribution of material in cassette and audio-diskette forms; leasing channels on CATV systems, TV (particularly as

TV-DSB develops worldwide), and existing radio facilities (AM, FM, and HF); and radio-DSB (see 6. below). While there is little availability at present of programmable audio recorders, or market for them, the addition of such recorders to shortwave radios could permit capture of VOA HF transmissions made in non-prime hours for later playback at a time convenient to the listener. Transmission times could then be chosen for minimum interference and/or best propagation. See also 9. below.

6. The question of radio direct-satellite broadcasting (DSB) for delivery of VOA programming raises a large number of issues. Its advantages include freedom from present relay station siting problems for certain areas of the world, and perhaps greater resistance to jamming. Problems to solve include political issues (including frequency allocation), system design, and listeners having to all obtain new receivers. The present 26-MHz international broadcast band has been considered in several recent DSB proposals because it is an existing allocation that is very underutilized. However, only an estimated 10% of worldwide shortwave receivers in place can receive this band, thus new receivers would be required. For a variety of reasons, radio-DSB at UHF appears to be a better choice if a frequency allocation can be obtained at future international radio conferences. Time is short and this matter should have a high priority.

7. Any utilization of new receiver facilities, whether it be for satellite broadcasts, for changed frequencies such as 26-MHz, or for better reception depends upon millions of persons worldwide buying the receiver equipment. That means that shifting to new means of communication is a decade-long process, during which the present shortwave frequencies and types of reception facilities must continue to be the major medium used. It also means that in plans for moving to more modern means of transmission, incentives must be provided to the world public to adopt the new technology.

   Relatively few people will buy new receivers to listen to VOA alone. They will buy them to receive a rich and varied menu of radio broadcasts. So, to make satellite radio or other new approaches a reality, the United States should encourage the creation of common-carrier or cooperative arrangements whereby many different countries and broadcasters will use common facilities to air diverse messages and varied program material. In such an environment VOA will find its audience; without such many-sided development there will be none. It is therefore in American interests to encourage all countries to to participate in common-carrier arrangements and low-cost receiver developments that will make it possible.

8. Jamming, particularly that by the Soviet Union, has become a major international problem, polluting much of the allocated shortwave broadcast spectrum worldwide. Technical means to

break through to Soviet-bloc listeners are only marginally effective, and quite costly from the equipment and operations standpoints. While planning for such measures should certainly proceed as suggested herein, all possible means (political, economic, and cultural) to induce the Soviets and others who are jamming to desist should also be explored.

9. One of the best counters to increased congestion (and jamming) in the HF bands lies not at the transmitter, but at the receiver. While the quality of the receivers in the hands of listeners is not generally under the broadcaster's control, it might be cost-effective for the U.S. government to underwrite the development of improved shortwave receivers that could be mass-produced and distributed at a price affordable by VOA's listeners, at least those in the free-world. Improvements in selectivity, stability, and overload resistance in low-cost receivers would be particularly desirable. A programmable recorder for unattended capture of programs would also be helpful (see 5. above), and could built in. Subsidization of receiver costs might also be considered to aid distribution and sale to particularly important areas.

10. Overseas relay sites located within only one ionospheric reflection hop of intended audiences are crucial to delivery of competitive signals at prime local listening times. Present sites must therefore be maintained and upgraded, and

new sites sought to fill present coverage holes. The realities of multi-hop HF propagation are that stateside transmitters, even if technically augmented, cannot be competitive throughout much of Europe and Asia or in parts of Africa and South America. If VOA were to be forced to broadcast only from the Continental U.S., its signals in its priority listening areas would be heard for fewer hours per day, and even for those hours would be much weaker and much less reliable.

11. The question of small versus large transmitter sites for new construction has been examined and discussed with a large number of people. There has been general agreement that while the economics of construction and operation favor the combining of transmitters for a number of program services into a few large sites, having a larger number of geographically dispersed small sites offers much more flexibility in beam directions to counter jamming, and can be more cost-effective in terms of VOA's main goal -- delivering good signals to its priority audiences. The consequences of losing a small site are also less disastrous than losing a large site.

12. The reliability problems encountered in the satellite relay feeds activated in the past few years have encouraged VOA to maintain operation of its traditional HF relay feed system as a backup, despite substantial operating costs. Since the

problems have been mainly with the local PTT landlines from the downlinks to the sites, every effort should be made to arrange for on-site downlink antennas, making whatever reasonable political tradeoffs or settlements are necessary with the PTT's, so that the HF relay feed backup can be eliminated, or at least greatly reduced in cost.

13. Most of VOA's worldwide transmission facilities are at least two decades old, and becoming a maintenance burden. Some badly need replacement. In addition, most are lacking any degree of automation and require large on-site staffs for operation. Because of the remoteness of most sites, the risks of sabotage, and the complexities of VOA HF operations, it does not appear that fully automated, unmanned sites, such as used by U.S. domestic broadcasters and some foreign HF broadcasters, are feasible for VOA. There is, however, much more that the VOA could do with semi-automation. In acquiring new or replacement transmission equipment, every effort should be made to take advantage of those automation aids that are now commercially available to reduce site manning requirements. This could also increase capability for signal optimization (as in 1. and 2. above) and for coordinated, multi-site control for anti-jamming purposes.

14. It does not appear that VOA presently has any ongoing "crisis planning" activity to anticipate and prepare contingency plans for such events as losing sites on short notice from

accident or for political reasons, or abrupt changes in programming and target audience, such as occurred a year ago in the Polish situation. Just as the military has its war games to prepare for the unexpected, VOA should regularly conduct "what if" exercises to best prepare for whatever may arise in a world that seems increasingly unsettled.

15. It is clear that VOA has been suffering in recent years from staff shortages, resulting partly from increasing costs during a period of fairly level year-to-year budgets. This has hit Engineering particularly hard. Coupled with the problems of operating an aging plant and the lack of equipment money for computer aids (see 4. above), this has left VOA unprepared to cope with the technical planning for the facilities expansions and updates desired for the next decade. A most common comment from the sources consulted was that VOA's most serious need is to beef up its engineering, research, and development staff and efforts. Much has been initiated along these lines since last July, but we can only emphasize that this must be carried through and adequately supported with the necessary working resources so that VOA can cope in the future in the increasingly complex world of international broadcasting, i.e., continue to be able to reach its listening audience.

16. Finally, VOA should take steps to institutionalize access to information on technical matters, both within and outside the Government. It seems clear that other Government agencies know details of Soviet HF installations and operations that would be of great value to VOA in its planning for the future, but that there has been no regular channel of communication, possibly because of security considerations.* Informed opinion of technical experts in the private sector also needs to be made known at all levels of VOA on a continuing basis. VOA's mission is too important to the United States to be conducted without all the technical information and guidance that the country as a whole can bring to bear.

*In this regard, a contact at the National Security Agency who was sent a survey questionaire thought initially that he would be able to provide valuable answers, but later reported that he was unable to obtain approval to respond to the questionaire in any way.

I. VOA IN TRANSITION

VOA's mission is clearly stated in its mandate from Congress to be the voice of the United States' Government, and to provide a fair interpretation of events and information for its listeners. To achieve this, VOA has to maintain the proper level of credibility, interest and professionalism so that a large, and important segment of the world takes it seriously, regularly turning to the VOA's outlets to keep informed, educated, and perhaps even entertained. No one element of the VOA's communications resources will be sufficient to accomplish this task; only the VOA taken as a whole can reach this understanding among the world's listeners. Our assignment is to assess the role that modern and changing communications technology should play in this procedure.

Despite the continual changes in the world political and technological situation, the Voice's staff have done a remarkably good job over the years in keeping up with the transitions. Microelectronics, satellites and computers are, however, rapidly changing telecommunications technology, and changes in broadcasting itself can be expected to accelerate in the next decade or two. This may further dilute VOA's ability to discharge its important responsibilities. Since the Second World War, when the Voice of America was formed from the private international short-wave stations of NBC and CBS, high-frequency radio broadcasting technology has remained relatively stagnant, while the high-frequency spectrum has become more crowded, jamming from Soviet-bloc countries has increased, and shortwave listeners have had an increasingly novel array of alternative channels vying for their attention.

Increasingly, the demand for news, information and entertainment, formerly provided to remote regions of the world by short-wave broadcasters is being met by other media. Sound and images with consistently higher quality than that delivered by HF has diverted potential audiences. Where once the backwaters of the world could stay in touch only by HF radio on a daily basis, today in virtually every corner of the globe one finds the ubiquitous cassette recorder with its hi-fidelity recordings. In most urbanized regions, we have seen the recent growth of higher-power medium-wave AM radio stations, FM broadcasts, and broadcast television. Coming rapidly, to the more affluent elite audiences, are videocassettes and videodisks; and on its heels, satellite-based national television systems may provide video delivery even to the least affluent areas.

Yet VOA's overwhelming task of providing daily broadcasts via a complex worldwide network, coordinated with demands for spectrum from allied and friendly countries, and hampered by jamming and its functional equivalent -- interference and band-hopping -- by competitors, is not to be taken lightly. For at least the rest of this Century, short wave broadcasting will remain as important as it has been, and probably more so. In an ever more interdependent and shrinking world, communicating America's message will be increasingly important in achieving the legitimate foreign policy goals of the people and government of this country. New means of communicating the message, such as satellite television broadcasts, international computer networks, and international direct dial telephony will be coming into use. While the time for planning for such novel means of international communications is at hand, nothing on the horizon is going to seriously reduce the importance of short wave listening until well into the 21st century.

In the United States, where few people ever listen to foreign broadcasts, it is easy to underestimate the significance of international broadcasting. In this country studies show only about 2 per cent of the population making any use of short wave. (2) That fact, however, only shows that the American public has basic confidence in the domestic sources of news available to it. In general, one finds a close correlation between lack of confidence in domestic news sources and turning to foreign radio

(2) Smith, Don. D., "America's Short Wave Audience", Public Opinion Quarterly, Vol. 33, pp 537-548.

for information. In countries where there is heavy censorship and news control the audience for foreign broadcasts is massive. About a billion persons can receive shortwave broadcasts. Based on careful research, VOA has estimated that it has an audience of 66 million persons who listen at least weekly, and that 38 million of these are in the Soviet Union and Eastern Europe where distrust of the local news sources is widespread.

In these "denied" areas, not only is there an eagerness to listen to foreign broadcasts, but there is also no alternative means of communication of comparable value. Foreign travel, contact with foreigners and circulation of uncensored printed material is severely restricted. But the governments of those countries have not dared to deny their people shortwave sets. For one thing, people in the market in those countries generally will not buy radios without some shortwave capability. In the Soviet Union a moonlighting profession has grown up of people who can adapt sets to receive foreign shortwave broadcasts. Also, the Soviets because of their large land mass have to use some shortwave to broadcast to Siberia, and so their standard sets have shortwave capability for frequencies up to 15 MHz.

But it is not just in the censored Communist world that short-wave broadcasting serves peoples' needs. In poor countries that have underdeveloped news facilities and low press circulation millions of people turn to such sources as the BBC and VOA to keep themselves informed about world events. For much of the world's population, therefore, international broadcasting plays a vital role in helping the population maintain a realistic and accurate image of what is really going on. From the American point of view, it helps to keep them informed about the real viewpoints and activity of our country, in contrast to what is portrayed by biased opponents.

While there may be billions of people too discouraged to care, there are in every country, no matter how dictatorial or free its regime, an alert, usually educated, stratum who are intensely interested in looking at foreign experiences and models for their country. These professionals and politically minded people form a growing audience for a "world service" that is not necessarily addressed to their country. They are the target of the world service programs provided by the Soviets as well as those from the West. Many of them are willing and even eager to listen in English. There is, thus, both an audience for foreign language programs addressed to the particular interests of the countries to which the broadcasts are aimed, and also for world service programs in English addressed to the internationally minded "upscale" audiences. The differences in level and style of these two kinds of programming are not our subject here. What is relevant to us in this report is that both kinds of service are needed and each requires its appropriate means of delivery.

Any change in VOA's facilities intended to meet those needs has to be planned carefully, weighing the many options, and delineating the risks if change comes too fast or too slowly. Nevertheless, the change is basically being forced from the outside in a radically changing world of listeners and broadcasters.

PROBLEMS

The specific problems to be faced by VOA in the coming two decades can be broadly separated into the following areas, some of which overlap considerably:

1) Signal delivery strength -- the ability to make itself heard reliably and well in those areas of the world where the United States Government needs to deliver news, views, and educational materials;

2) Spectrum availability -- the need and ability of all nations to make themselves heard in the HF and MW bands;

3) Jamming -- the negation of the usefulness of much of the best HF broadcast spectrum by Soviet-bloc, and other countries, with effects far beyond their borders;

4) Audience fragmentation -- the ability to get its message heard in an world of information-overload;

5) Resource management -- the ability to coordinate a complex network, plan for the future, develop along with new technology, and attract the necessary skills and talent within the framework of the Federally-funded and operated agency, and do so in a most efficient manner.

SOME SOLUTIONS

The solutions to these problems rests in the correct mix of technology, politics, and management strategy. The VOA will have to remain fluid in its approach, since no one way points to the future. These solutions will be found in these areas:

1) Technological changes -- signal delivery parameters, more efficient utilization of the broadcast spectrum and use of other modes of program and information distribution, and use of modern management tools based on computers and highspeed telecommunications systems;

2) Political measures -- an approach which encourages the most stable set of broadcasting methods and means in an increasingly unstable world political arena;

3) Management reorganization during a continuing transition without disrupting VOA's primary mission of daily broadcasting.

SHORT-TERM VERSUS LONG-TERM GOALS

In the near-term, VOA will have to face increasing pressures to reach certain specific audiences; these problems may be separated from the longer-term goals of utilizing novel technologies such as satellites, digital wireline communications, video and electronic text displays. However, a transition must be designed so that clearly defined short-term solutions do not impinge on less precise long-term evolution.

II. SIGNAL DELIVERY AND SPECTRUM UTILIZATION FOR DIRECT VOA BROADCASTING

A. SIGNAL DELIVERY

1. BACKGROUND

In delivering listenable audio signals to its world-wide audience via HF broadcasting, VOA has three types of interfering signals to overcome:

- noise from various sources (the radio receiver, man-made but non-radio electrical "static", and natural HF energy),
- interfering signals of other HF broadcasters,
- deliberate jamming of VOA broadcasts.

Life would be a lot easier for both VOA and its listeners if only the natural and man-made, non-radio noise sources were involved, since these are almost always much weaker than radio interference, whether from other broadcasters or from jamming.

The VOA has designed and operated its facilities for a number of years with a goal of delivering a signal (field) strength of one millivolt per meter or more in its intended listening areas.

This goal is not always realized, but is the standard in the absence of jamming. For transmissions that it expects to be jammed, the minimum signal strength goal is raised to 2.5 millivolts per meter. The one millivolt per meter level is considerably above the sensitivity of almost any HF receiver (the better ones have sensitivity down to one microvolt at the antenna terminals), and also generally well above all but the worst levels of environmental (non-radio) noise. It was based on overcoming interference from other HF broadcasts.

HF international broadcasting has quite a different interference situation than AM, FM, and TV broadcasting in the U.S., where transmitter-site/frequency pairs are assigned so that strong signals are spaced a number of channels apart for any listener. (Few receivers are selective enough to separate strong signals on adjacent channels.) In HF broadcasting, the long reach of the signals via sky-wave propagation, combined with the large number of broadcasters, makes such neat separations almost impossible. Despite the best ITU coordination of transmitter sites, frequencies, and beam directions, a listener will often find that co-channel and adjacent-channel signals are so strong that they cause interference with the signal that he wants to hear. Deliberate jamming is usually even stronger for listeners in the areas at which the jamming is aimed -- it is designed to prevent the message of the foreign broadcaster from being heard at all.

The extent of mutual interference among HF broadcasters is indicated by the results of the ITU coordination process performed four times yearly. This is available in the ITU broadcasting schedules document. For each of the thousands of coordinated program transmissions, calculations are made to determine those expected to interfere with it and cause a signal-to-interference ratio of less than 11 dB (a factor of 3.55). On the average, there are about five such interferences listed in the schedule for every program transmission, with a range from none to over 20 interferers.

The problem of co-channel and adjacent-channel interference is compounded by a lack of discipline among world broadcasters -- some of them often operate on frequencies and beam directions other than the ones submitted to the ITU for coordination. This often may be a result of trying to find a "quiet" spot. There is also evidence that the Soviet Union often operates transmitters carrying internal programming so as to interfere with VOA programming in ethnic Soviet Union languages. This is jamming, but they say that it is not -- it is just their internal broadcasting.

In the immediate post-World-War-II period, when there were fewer HF broadcasters than today, mutual interference was a minor problem; satisfactory signals could be delivered with transmitters of 25-100 kW power. In the 1960's, many HF broadcasters, including VOA, began to increase power to the 200-300 kilowatt range; 250 kW was adopted by VOA as a "standard" for new installations. VOA currently has 56 250-kW transmitters in operation: twelve at Greenville are arranged in six pairs, each of which can output either 500 kW or 250 kW (only one output line to the antenna switch matrix is provided for each pair). In the last few years, other countries have built 500-kW transmitters, with 81 now in operation, and another 31 planned or on order. The VOA currently has no 500-kW transmitters overseas, but it has requested FY 1983 funds to install four in Sri Lanka broadcasting to the mid-Asian continent, and is considering whether 500 kW (or more) should become its new standard.

Because of the vagaries of sky-wave propagation, VOA adopted another standard years ago: that at least three different frequencies should be used simultaneously to cover a listening area the width of one time zone. This is a major factor in the number of sites and transmitters required to deliver VOA programming since it requires three transmitters per program. For additional time zones, VOA standard operating procedure calls for use of one or two additional transmitters. Thus, to cover all of the Soviet Union as far East as the Urals, VOA schedules 5-7 transmitters (if available), all carrying the same program. This number is increased by one transmitter per time zone if the program is being jammed.

The following sections discuss VOA's options, and some opinions expressed by persons interviewed, for improving ground-based HF signal delivery capability in the coming decades.

2. HIGH-POWERED TRANSMITTERS.

A world-wide power race is underway in HF transmitters, as we have noted. In order to keep its signals competitive, VOA has made plans to go to 500 kW in some or all of its new installations. Unfortunately, this will have a major impact on operating costs since electrical power for VOA relay stations is currently about 50 percent of total site operating expenses. The Philippines Relay Station, for example, had FY 1982 operating expenses of $4.1 million (including local employee salaries and benefits), of which $2.2 million was the cost of power. Initial capital expense will also be greater for transmitters, and for 500-kW rated antennas, feed lines, and switching matrices.

No U.S. company currently has a production design for HF transmitters larger than 250 kW. The 500-kW units being acquired by other countries are made primarily by Brown-Boveri (Switzerland), Telefunken (West Germany), and Marconi (U.K.). * All of these transmitters use a new technique called pulse duration modulation (PDM) which permits an improvement over the usual 50-55 percent power efficiency of standard transmitters. PDM performs a second modulation by pulsing the transmitter on and off at a kilocycle rate sufficiently higher than the 5-kHz

* An additional issue would be the negative effect on U.S. balance of payments for high-power equipment.

audio modulation so that it does not degrade the audio. This creates higher-frequency sidebands that must be filtered out before transmission to keep the transmitted bandwidth approximately the same as for standard 5-kHz audio modulation. But, since the transmitter is not on all the time, it uses less average power for the same peak power.

We have been unable to get solid information on the power efficiency of PDM transmitters during this study, and found that although VOA Engineering had some brochures, they had not had time to investigate PDM characteristics in any detail. We have heard efficiency numbers ranging from 60-80 percent from various sources. Using this spread, a 500-kW transmitter would use somewhere between 30 and 70 percent more power than a standard 250-kW transmitter, with the number more likely lying between 50 and 70 percent more power. If it is assumed that 80 percent of the total power usage of a relay station is by transmitter final amplifiers, then a station with all 500-kW transmitters would use somewhere between 40 and 56 percent more power than an all-250-kW station. For the Philippines Relay Station discussed above, this would be an additional cost of $900,000 to $1,300,000 per year at current power costs.

We have also encountered a divided opinion as to the wisdom or necessity of making 500 kW a new VOA standard power. Some point out that this brings only a 3-dB improvement in signal strength at a substantial increase in operating cost and that larger improvements in signal strength delivered to listeners can be obtainable at less life-time cost by other means, such as use of higher-gain antennas or dynamic optimization of sky-wave signal strength in the listener area. These will be discussed in the next section.

Others expressed foreboding over the electronic pollution caused by "super-power" transmitters, and feel that there would be no necessity for all parties to increase power if the bands were not so crowded. They suggest that the clearing of the band extensions adopted at the 1979 WARC should be expedited so that present stations can begin to spread out. These expansions were to be phased in after a 10-year waiting period. * Beyond that, it is felt that consideration should be given in future world radio conferences to the allocation of more bandwidth for HF broadcasting, on the basis that long-range broadcasting is a better use of the special sky-wave propagation characteristics of the 3-30 MHz spectrum than the many present point-to-point radio communications services which could be moved to alternate, non-HF technologies. It should be noted that the present 12 HF broadcast bands total 3.155 MHz. However, the 8 most useful bands (5-21 MHz) total only 2.16 MHz, less than one-half the bandwidth

* Many countries other than the U.S. are already operating "out of band," i.e., in the new extensions, but this is not officially condoned, and the ITU does not at present coordinate transmissions in the band extensions.

of one TV channel, and only 10.8 percent of the 3-30 MHz spectrum. The 1979 WARC approved band extensions totaling 780 kHz for HF broadcasting (2.9 percent more of the 3-30 MHz spectrum), but the extensions were not supposed to be used by broadcasters before 1989, with some not until after the year 2000.

Other people interviewed in the course of this study have cited the greater design and operational problems of "super-power" HF transmitters compared to present 250-kW designs. Chief among these are the higher voltages and currents that must be handled by the antenna switches, feed lines, and antennas, with much greater proclivity for arc-overs, burn-outs, and grass fires. (We were told that the present 500-kW transmitters at Greenville, North Carolina, have many more outages for this reason than the smaller transmitters, and that grass fires in the antenna field are a constant hazard.) The cooling provisions for super-power designs are also more difficult because more heat loss is concentrated in a single power amplifier. This is, of course, not true for coupled designs, such as the present 500-kW transmitters at Greenville.

One way to obtain higher HF power without the above problems is to use phased array techniques, in which several separate transmitters, each driving a separate antenna, produce a single broadcast beam. The power combining then takes place after the signals have left the antennas, and no system element has to handle the total power. It has been reported to us that a VOA Engineering study was made a few years ago of the possibilities for "super-power" stations, and that the conclusion was that the multi-transmitter, multi-antenna approach was preferable to having large single transmitters driving single antennas, for the reasons cited above.

The USAF/General Electric high-power, HF backscatter radar under experimental test in Maine is an example of the phased array technique. This is based on developmental work at Stanford University. (5) In the experimental Maine radar, which presently operates on frequencies from 6 to 22 MHz (and will be expanded to cover 5-28 MHz), 12 separate 100-kW transmitters each drive a separate element in a linear, phased array antenna 2,265 feet in length; a megawatt fan beam (broad in elevation) is created which is controllable in both azimuth beamwidth and azimuth direction by low-power phase-control electronics in the transmitter exciters. Depending on the frequency, the beam can be as narrow as a few degrees, and it can be swept through 60 degrees in azimuth.

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(5)
"Backscatter Radar Unit Enters Production Phase," Kenneth J. Stein, Aviation Week & Space Technology, August 16, 1982, pp 68-69.

A decision to make 500-kW unit transmitters a new VOA standard should be made only after a systems study which includes careful consideration of the advances in signal delivery that could be made by some combination of:

- innovative changes in the way broadcast beams are generated
- the dynamic optimization of transmission parameters to account for actual ionospheric propagation conditions, and, wherever possible, the expected noise levels in the most important reception areas
- centralized, real-time network control

These possibilities are expanded upon in the next section.

3. ANTENNA TECHNOLOGY

With few exceptions, all the antennas at VOA relay stations have fixed azimuth beam directions and elevation launch angles. They also generally have rather broad azimuth beams -- 40 to 70 degrees on the lower HF bands, and 20 to 40 degrees on the higher bands. (Antenna gains are an inverse function of beamwidth, and range from 15 to 25 dB from the lower to the higher frequencies.)

There is some flexibility in elevation launch angle for particular broadcasts in that some azimuth directions at some relay stations have two different launch angles available for switching (either two different antennas on the same azimuth, or an antenna that is high-low switchable). Almost half of VOA's 325-odd antennas worldwide are of rhombic design with little or no possibility of beam controllability, and almost all of the remainder are of curtain design. Curtains, being an array of radiating elements, can accommodate beam control through feed phasing. Most of VOA's curtains, however, are installed to have fixed azimuth and elevation angles. The few exceptions are a single two-azimuth curtain at Greenville, North Carolina, Site A (recently installed for South American service), 14 two-elevation curtains at Kavala, Greece, and all the curtains at Woofferton, England, which have both high-low and +/- 12 degree azimuth switching. The BBC, however, has indicated that it will exercise an agreement right to take over VOA's six-transmitter Woofferton facilities, and wants to do so in 1990. Worldwide, VOA also has about a dozen low-power antennas of other types (log-periodic, etc.). Some of these are steerable through 360 degrees.

The choice of antenna beamwidth (and thus antenna gain) is largely set by the ground area one intends to cover with a single broadcast at a given distance from the transmitter. It is apparent that the VOA philosophy has always been to cover fairly large areas for most broadcasts, thus the installed antenna characteristics as described above. It has been suggested that in the face of increased interference from other broadcasters and jamming, VOA should consider more directive, higher-gain beams if it wants to break through to certain high-density audiences. The question might be posed another way: is it better to broadcast to all of Western USSR for several hours with possibly non-competitive signals except in rural regions, or to focus available power on a sequence of smaller, high-population areas for shorter periods each? If the answer is the latter, then new types of antennas having more directivity and fast-slew control of beam directions in small angular increments will be required.

A recent paper suggests that the Soviet Union may have already adopted the above philosophy. The author of this paper notes the fact, as has also been commented on by others, that for programs directed at North American listeners, Radio Moscow is delivering a much stronger signal than either the BBC or the Deutsche Welle, despite the fact that the distance from the Soviet transmitters is much greater. He postulates that the Soviets are using much larger curtain antennas than VOA and other free-world broadcasters (more bays and/or more stacks), and that because of apparent "tune-up" variations in signal strength at the beginning of broadcasts, that they are also dynamically optimizing transmission parameters. (6)

In HF sky-wave transmission, a number of factors determine the distances away from the transmitter that the signal strikes the earth on its first, second, and subsequent hops, and the consequent signal strengths delivered to each location. Chief among these are the heights of the various ionospheric layers along the transmission path, their reflection/absorption characteristics for various frequencies, the transmission frequency used, and the elevation launch angle and elevation beamwidth. Only the frequency, the launch angle, and the elevation beamwidth are under the broadcaster's control -- the ionospheric parameters for a particular path vary widely over

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(6)
"Why Radio Moscow is WINNING the dB WAR," Stanley Leinwall, Radio-Electronics, December, 1981, pp 55-57.

each day as the Earth rotates, from season-to-season (with the Earth's precession), and as a function of solar activity (sun spots).

VOA has predictions made for the average expected transmission conditions over future one-month periods for each transmission path of interest from each of its relay stations (some 200 paths in all). These predictions are made by NTIA/ITS (Boulder) with the HFMUFES 4 computer program, which has the frequency bands, gain patterns, and beam directions of all VOA antennas in its data base. The result is over 500 pages of printout that list, at two-hour intervals over the average day, the maximum useable frequency (MUF) and the lowest usable frequency (LUF). Also listed for each HF broadcast band at two-hour intervals are predicted best signal-delivery parameters:

- the particular antenna used for calculation
- the predicted best propagation mode
- the number of hops along the path
- the best elevation launch angle for the mode
- the gain of the antenna at that launch angle
- the estimated delivered signal strength
- the estimated reliability of the mode over the month

Note that the gain of the chosen antenna is automatically reduced from its maximum beam-center value to account for any angular offsets of the beam center from the path azimuth and from the optimum launch angle for the propagation mode.

The prediction data is used in VOA's four-times-per-year scheduling process to select which frequencies and antennas should be used from which relay stations to deliver particular programs during a broadcasting period. (The four annual periods are: Sept.-Oct., Nov.-Feb., Mar.-April, and May-August.) Since proposed schedules are coordinated with the BBC and the Deutsche Welle before they must be submitted to the ITU six months in advance of the broadcast period, the prediction data used is run about eight months in advance. There are opportunities for some changes in a schedule up to one month before it goes into effect, but by and large, VOA operations are based on ionospheric predictions made over a half a year in advance.

We have discussed this situation with a number of knowledgeable people, and found a difference of opinion. Some feel that the current HFMUFES program is so good that there is little to be gained by attempting to dynamically assess the state of the ionosphere and correct transmission parameters accordingly. Others say that actual conditions cannot be predicted with great accuracy that far ahead; and, even if the predictions of average conditions for a month <u>are</u> good, day-to-day variations from the average are at least +/- 20 percent. They thus feel that dynamic correction should have a payoff.

We have attempted to learn what we could about the backscatter sounding technique for assessing delivered signal strength and picking the best of available elevation launch angles. Experimental measurements made on VOA facilities in 1967 by Stanford Engineering Laboratories and VOA engineers have been reported. (7) These tests, made between Greenville, N.C. and a receiving point in Rolla, Missouri, indicated that backscatter echos could be used to pick the better of two elevation angles (high and low) about 80 percent of the time. In some cases, the signal strength difference in Rolla (a one-hop path) was as much as 12 dB. VOA apparently made some subsequent operational trials of backscatter sounding in South American programming, but without much success in improving its signals into a particular area of Brazil, and abandoned the technique. (We have been told that later tests and computer simulations showed that the difficulty in these trials was not the fault of the backscatter technique -- the particular area for which signal optimization was being attempted is in a propagation "hole" for the transmitter site involved.)

We have also learned from our interviews that RFE/RL used the backscatter sounding technique extensively for a number of years

(7)
"Elevation Steering of HF Broadcasting Antennas Using Backscatter Sounding," J. M. Lomasy and R. B. Fenwick, Technical Report IA-5 (SU-SEL-68-031), Stanford Engineering Laboratories, June 1968.

during the 1970's with good results, but it now feels that the HFMUFES program predictions are so good that sounding gives little improvement. RFE/RL have not been using sounding for several years.

In regard to the VOA and RFE/RL tests and uses of backscatter sounding mentioned above, we note that neither organization had antennas with fine control of elevation angle, and could only choose between two angles -- high (typically 20-26 degrees) and low (typically 8-10 degrees). The tests and trials may therefore not have been able to demonstrate the real value of elevation slewing for best backscatter echo. For example, examination of typical HFMUFES output data shows that the calculated best elevation angles for particular paths vary over the range 1-30 degrees depending on the mode, frequency, and time of day. (8) In making each signal strength prediction, the program reduces the beam-center antenna gain in accordance with the angular difference between the launch angle for the best propagation mode and the physical beam angle of the antenna. In many cases, the angular difference is a substantial fraction of the antenna elevation beamwidth, and the resulting antenna gain in the optimum launch direction is as much as 5-8 dB lower than its beam-center gain. (The gain used in the computation is made

(8)
"Radio Propagation Predictions of the High-Frequency Broadcasting Bands," (for December 1981), Frequency Division, VOA.

even lower if the beam center in azimuth is not pointing directly at the desired target area.)

The particular high and low angles that have been designed into VOA's antennas certainly represent prudent compromises if one has to pick between just two angles. However, if the best launch angle determined by ionospheric conditions is half-way between, as it often is, then both the high and low angles will give approximately the same result, and neither will have full gain in the best launch direction. The gain loss is as large or larger than the 3 dB that would be gained by doubling power. The same loss in gain occurs if the optimum launch angle is near either end of its 1-30 degree range.

It should also be noted that if, as discussed earlier, it is desired to raise signal strengths by using beams narrower than those now used by VOA, gain fall-off due to antenna-beam pointing errors will be even more severe, and fine-control beam slewing capability would seem to be a prerequisite to their use.

One propagation specialist consulted noted that in the past it was thought that the reflection characteristics of the ionosphere were so dispersive as to preclude an initially narrow beam staying that way after one or more hops. He said that this is no longer considered to be true. He feels that the use of narrow beams to increase delivered signal strengths is quite feasible.

The sum total of all of the preceding is that there appears to be the possibility of much larger increases in HF signal strength delivered to critical audiences through innovations in antenna technology (including dynamic beam control) than through increases in transmitter power, and at much less increase in annual operating costs. We therefore recommend that VOA thoroughly investigate what is now possible in very large steerable arrays (including those with phase locked multiple transmitters) before deciding on 500 kW as a new transmitter standard. In this regard, we have been told by one maker of HF antennas that it is probably now possible to build a very large antenna (8 bays and 8 stacks) that would operate on four contiguous bands (present VOA curtains operate on no more that two adjacent bands, e.g., 7/9 Mhz, 9/11 Mhz, etc.). He also says that the ability to obtain fine control of elevation angle is contingent on having a very tall antenna (e.g., 8 stacks) that would generate narrow vertical beams and reduce the effect of the ground image antenna on the radiated pattern.

As mentioned earlier, VOA programs are not all delivered on single frequencies from single antennas, or necessarily from a single relay station (the three transmitters per time zone rule). If dynamic beam control is instituted, relay stations should no longer operate independently, each following its own facilities usage schedule determined at VOA headquarters months earlier, but as an interconnected network that can adapt as a whole to the signal needs of the moment.

Backscatter sounding appears to have sufficient potential for signal optimization that it should be further investigated in the context of antennas having finer control of antennas that those used in VOA and RFE/RL testing to date. It should also be noted that a number of people have commented that there is an alternative to backscatter sounding for dynamic signal optimization -- an expanded monitor network with real-time feedback to the transmitter sites. More will be said about this in a later section.

Finally, all of the above addresses only one-half of the problem of delivering VOA's message to the ears of listeners: i.e., transmission. At least one of the persons interviewed, and one with a good deal of listening experience in the Indo-European area, said that getting better receiving equipment into the hands of VOA's audience would have a far greater effect in reducing interference problems than increases in transmitted power. This could include receiving antennas with more directivity and possibly selective discrimination against ground-wave jamming, and receivers with much better selectivity than present mass-market types. This and other receiver issues are discussed later in Section II-B.

4. MONITORING.

At the present time, VOA has a worldwide monitoring network consisting of eight full-time stations manned by VOA personnel; approximately 30 contract listeners, usually U.S. citizens resident or on stationed temporarily abroad; and about 25 volunteer listeners, short-wave fans who are citizens of various countries and who have agreed to report on the quality of VOA reception. Listener reports, submitted on forms provided by VOA, are processed in Washington to yield an overview of VOA's performance in delivering its message.

The impression we have gained is that feedback and processing of listener reports, at least those from non-VOA sources, is a slow, "see-where-we've-been" process. For example, the listener-report computer run of May 13, 1982 was for March and April, the previous broadcast period. This is better than it seems to have been in the past. A former VOA engineer said that while he was there a few years ago, listener reports were often stacked up for six months or more waiting to be computer processed. Personnel shortages and lack of access to computer facilities were cited as principal problems.

A strong suggestion from one interviewee is that VOA should do much more with monitoring. He suggested that VOA should both expand its network of full-time monitor stations and institute real-time reporting. He said that a properly designed monitoring system could account for the effects of interference -- from jamming or otherwise -- and, wherever it could be done well and reliably, could be more effective than backscatter sounding in optimizing transmission parameters.

Audience correspondence is another potential source of information on VOA signal effectiveness. The BBC, for example, places great weight on listeners' views, with a department dedicated to reading and responding to letters. In 1980, the BBC handled over 350,000 such letters. It also mailed out questionaires, receiving 19,000 answers. (9) Our information, however, is that VOA places little emphasis on responding to listener letters, and that many go unanswered, or are answered only after a lengthy delay. Not only is VOA losing an opportunity to build its image, it is also losing information on signal performance which could be gleaned from an expanded base of corresponding listeners.

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(9)
BBC Annual Report, 1982.

5. SITE ISSUES

Under proper ionospheric conditions, HF signals can, and do propagate strongly half-way around the world. However, due to the ionosphere's inherent instability, the more times a signal has to bounce up-and-down between it and the Earth, the less reliably a signal's propagation can be predicted. Predictions for one or two hops, and distances of one to two thousand miles, are fairly predictable, but at longer distances and for more than two hops, deviations become serious.

Therefore, for reliable worldwide coverage, VOA has wisely dispersed most of its HF transmitters in ten overseas relay stations. Direct-broadcast programming from HF transmitters at Greenville, N.C., and Bethany, Ohio is intended primarily for listeners in Latin America and parts of Africa. VOA also uses medium-frequency (MF) transmission from some overseas sites to provide local ground-wave coverage up to a few hundred miles. These MF transmitters are in Kavala and Rhodes, Greece; Munich, West Germany; Bangkok, Thailand; and Botswana. Sites in Florida and Antigua transmit MF to the Caribbean.

One of the issues facing the VOA is what to do about its four HF sites in the U.S.: Greenville, North Carolina; Bethany, Ohio; and both Delano and Dixon in California. Dixon is currently in mothballs, having been deactivated in 1979. All VOA programming is generated in the Washington studios and, except for the direct-broadcast functions of Greenville and Bethany, the U.S. sites principally feed VOA programs to overseas relay transmitters. Now that most primary feeds are by satellite, many in VOA and USICA feel that the relay functions of the U.S. transmitters have become superfluous, and a costly luxury to maintain. Others in VOA have maintained that despite the extra operating costs, HF transmitter feeds from the U.S. and the HF receiving facilities at overseas relay stations are vital and should be kept in constant operation as an instantaneous backup in case of satellite circuit outages. Some also feel that U.S. sites need to be maintained, and possibly augmented in capability, for direct-broadcast duties in case key overseas sites are lost due to political or other catastrophes.

This question of HF backup for satellite feeds is not a technical issue as much as a philosophical one. HF-feed capability would probably not have been built had satellite circuits already been in use. But, the HF feeds were there first, and there is thus an element of "status quo" in maintaining HF feeds simply as backups for satellites. To some extent, this has been fostered by past unreliable satellite links, primarily the terrestrial connections maintained by the local telephone authorities. In a later section, we discuss the technical and political probabilities of reducing satellite feed outages to a vanishing point, removing any need for backup.

The feed question is also related to the broadcast-backup question. If it is desired to maintain a quick-reaction capability to back up overseas relay sites with state-side transmission facilities, all such VOA transmitters must be kept operationally ready. For high-power radio equipment, this requires almost daily operation to prevent equipment deterioration and to maintain a staff familiar with its operation.

The Dixon relay station illustrates the problem of trying to bring idled equipment on the air after extended non-operational periods. Dixon was deactivated in 1979 and placed in caretaker status. Current VOA plans call for it to be reactivated for additional Spanish-language programming directed at Central and South America. But reactivation will not be a simple matter. The GAO has recently estimated that it will cost $1.5 million to reactivate Dixon, and that it will take six months just to get the transmitters operating again. VOA Engineering estimates that the reactivation cost will be considerably less ($200,000), but we have not seen their time estimate. Complete station shutdown, such as Dixon, is an extreme case, but these problems would be encountered to a lesser degree with idled equipment and reduced staff at operating stations. *

Because the distances from the U.S. to VOA's audiences is much greater than from overseas relay stations, with more ionospheric hops required, broadcasting directly from the Continental U.S. could only be done with greatly reduced effectiveness even if significant improvements were made in present facilities. Under the best of circumstances, these distances and hops reduce signal strengths, but also from the U.S. there are fewer hours per day for "good" transmission than from present overseas sites.

Difficulties of stateside transmission are shown in a comparison of the December 1981 HFMUFES predictions of transmission to the Moscow region from Kavala, Greece and from Greenville, N.C. (11) Figure 1 plots the predicted signal strength range of the best four frequencies at two-hour intervals from Kavala (top curve) and from Greenville (bottom curve). Both curves are based on 250-kW transmitters. Signals for the best four Kavala frequencies are all 2 millivolts per meter or greater for the evening hours (5 PM to 9 AM Moscow time), and 1-2 mV/m during the day (9 AM to 5 PM). Signals for the best Greenville frequencies, however, are never over 0.5 millivolt per meter, and dip to less

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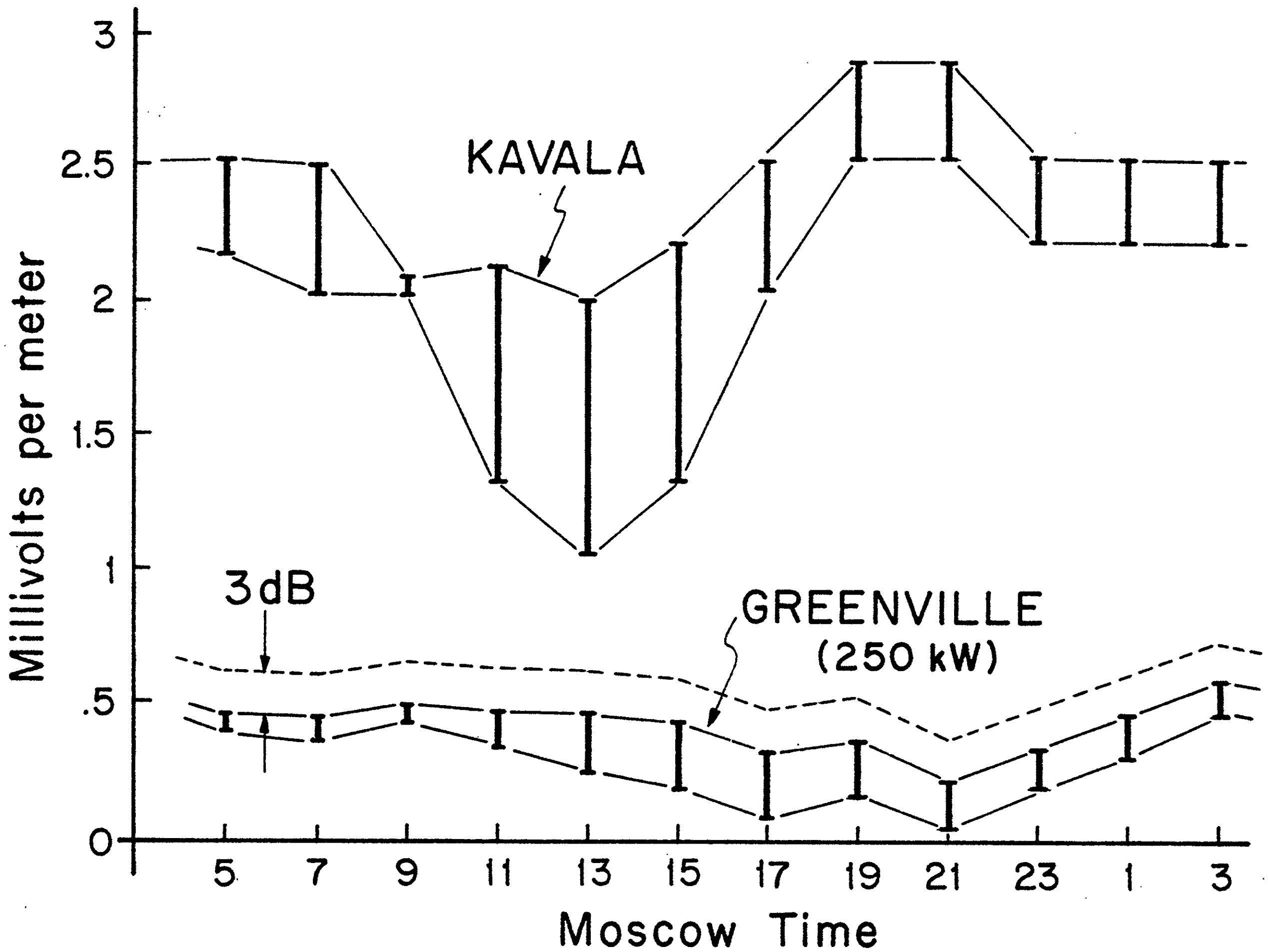
* A further non-technical problem is that if ITU-registered frequencies are not used at frequent intervals, other broadcasters begin to pirate them.

(11) VOA, Ibid.



Notes: 1. Vertical bars represent range of predicted signal strengths for the best four frequencies at each hour.

2. Dashed curve shows effect of 500kW from Greenville

Fig. 1 Comparison of Predicted Signal Strengths in Moscow for Kavala and Greenville 250kW Transmitters, December 1981.

than half of this in the evening "prime time," 5-11 PM. At 9 PM, the best Kavala signal (9-MHz band) is 22 dB greater than the best Greenville signal (21-MHz band), or 12.6 times as strong in field strength in the reception area. Even at the worst time of the day for Kavala (1 PM), its best signal is 4.5 times as strong as the best Greenville signal. Greenville does, of course, have 500-kW transmitters, and these would raise the HFMUFES numbers by 3 dB, a factor of 1.414. * The dashed curve in Fig. 1 is 3 dB above the strongest Greenville signals -- still far below the Kavala signals.

If distance were the only factor, Greenville signals would always be 12.6 dB weaker than Kavala signals, for the same transmitter parameters, and this is the approximate difference shown in Fig. 1 during the hours from midnight to 9 AM. The other relative variations are the result of changes in ionospheric reflection efficiency along the respective transmission paths.

Signal strength is not the whole story, however. Reliabilities predicted for the signal strengths shown are much higher for Kavala than for Greenville. Only for the 3-7 AM Moscow time period are the reliabilities approximately equal. In the prime (Moscow time) evening hours, 5-11 PM, Kavala reliabilities are in the 98-99 percent range, whereas predicted Greenville

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* Note: voltage is proportional to the square root of power.

reliabilities are in the 60-70 percent range. (A 70 percent reliability means that the predicted signal strengths would not be realized 30 percent of the time.)

VOA also uses transmitters in Munich, West Germany; Tangier, Morocco; and Woofferton (U.K.) to broadcast to the Moscow region. Munich (100 kW) and Woofferton (250 kW) signal strengths predicted for Moscow are comparable to those from Kavala, and provide several frequency choices for each hour of the day with 1 millivolt per meter performance or better. Tangier, being twice as far away as Kavala and having only 100-kW transmitters at present, generally delivers signal strengths of 0.5-1 millivolt per meter, but with a number of reliable frequencies for each hour of the day.

It can be concluded that if the VOA were to have to abandon the above sites, and could not obtain satisfactory alternative overseas sites, its voice in the Soviet Bloc would be much quieted compared to the present situation, and much more susceptible to interference and jamming. Were transmission to originate in the United States, much stronger beams would have to be generated through a combination of higher antenna gains and higher power, and dynamic optimization of transmission parameters would also seem to be required because of the low path reliabilities cited above. Even so, the service would be degraded considerably.

In regard to VOA's future overseas expansion, we have discussed with various people the strategy of a few new large stations versus a larger number of smaller stations with a more general geographic distribution. There was general agreement that the financial economies of scale favor fewer, larger stations. Because the cost of building and manning a small station is not proportionally less than that for a large station, dispersing a given number of transmitters into a large number of small sites will cost more in capital and operating expenses than grouping them into fewer, larger sites. This seems to be true even though the transmitter equipment needed to provide adequate signal strengths can be less costly if the small sites are located so that shorter transmission distances are involved than from the large stations.

Cost alone should not be the overriding consideration, however. The larger number of sites, the greater possibilities there are for being able to direct strong signals to specific areas af the large land masses of the Euro-Asian and African continents at the desired times of day. Beaming into Soviet-bloc nations from a larger number of directions can also help in regard to jamming, particularly of the sky-wave type. Also, the larger the number of stations, the less will be the effect of losing any particular site or sites due to political causes.

Therefore, in conclusion, there is a complex set of relationships among transmitter sizes and locations. As the VOA plans how to cope with the increased strengths and growing number of competing broadcast signals, with jamming, and with the possible loss of certain sites, it should certainly conduct trade-off studies which include cost-effectiveness analyses of various siting strategies, and the vulnerability issue. We discuss some of the political factors in Section II-C.

A final consideration regarding sites: one suggestion from someone quite knowledgeable in HF antenna design is that locating antennas on cliff edges would remove the effect of the normal ground image, making fine control of elevation angle more feasible. This could also help in achieving the very low launch angles that are optimum for some propagation modes.

6. JAMMING CONSIDERATIONS

After a hiatus of seven years, the USSR resumed jamming of VOA broadcasts to the Soviet bloc in August, 1980. Current jamming of VOA, RFE/RL, BBC, Deutsche Welle, Kol Israel, and Radio Peking transmissions to Soviet-bloc countries is extensive. Both sky-wave jamming for distant areas and ground-wave jammers for local, metropolitan areas are used by the Soviets.

Sky-wave jamming does not impede reception just within the Soviet-bloc countries; it affects areas far from the USSR. A March, 1982 survey indicates that a large percentage of all channels in the 7-, 9-, 11-, 15-, and 17-MHz bands are essentially useless in the evening hours, 1700-2300 local time in the locations indicated: (13)

Monitoring Location	% of Channels Useless
Belgrade	52
Helsinki	38
Vienna	51
Nairobi	57
Islamabad	46
Hong Kong	31
Washington	19

[These numbers are averaged from hour-by-hour percentages given in the reference for each band. Excluding Washington, the raw data spread indicates from 26 to 86 percent useless channels for particular band-hour-site combinations.]

(13) "A Study of the Impact of Jamming on the H.F. Broadcasting Bands" (undated VOA document, based on March 22/23, 1982 monitoring).

This deliberate negation of half of the most useful short-wave channels represents a worldwide problem that will no doubt be a major issue at the upcoming ITU short-wave conferences in 1984 and 1986. One person that is very much involved in frequency coordination and past conferences said that he did not see how the 1984 conference could succeed if jamming continues as at present.

Sky-wave jamming signals from a given transmitter are subject to the same propagation conditions as sky-wave broadcast signals; such jamming signals only strike the ground at intervals called the skip distance, leaving zones of relatively small signal strength in between. Unless these skip zones are jammed by other sky-wave transmitters in different locations, or by local ground-wave jammers, sky-wave broadcasts can reach into these "quiet" zones with a signal strength advantage over the jamming. There is also a phenomenon called "twilight immunity." As the ionosphere (particularly the F layer) changes from its day height to its lower night height in a given locale, it has a slope downwards from West to East. During this time, the higher HF frequencies will propagate from West to East, but not from East to West. This is already exploited by VOA in its broadcasts to the Soviet satellite states and Western USSR; frequencies are chosen which the Soviets cannot jam during twilight immunity with sky-waves transmitted from the interior of the USSR.

Except during the times of twilight immunity, the same propagation conditions prevail for both jammers and broadcasters. If both are assumed to be one-hop paths, the jammer has to have a substantial fraction of the broadcaster's power in order to make the broadcaster's message completely unintelligible to dedicated listeners willing to put up with very noisy signals. Increasing broadcast signal strengths therefore forces jammers to increase the jamming signal. We were unable to determine whether VOA's current goal of 2.5 millivolts per meter for jammed broadcasts is sufficient to ensure intelligibility in areas subject only to sky-wave jamming. Several interviewees only suggested that signals should be as strong as possible. Examination of the HFMUFES printouts indicate that predicted signal strengths into the Moscow region are often in the range 2-2.5 mV/m from stations such as Kavala (see Fig. 1) and from Woofferton, but not higher. The BBC and the Deutsche Welle coverage standards are lower. (14) The BBC strives to achieve 1 mV/m, 90 percent of the time, and recognizes that this is usually not possible for the longer distances. It feels that 2.5 mV/m is generally impossible to achieve with its present sites and equipment. The Deutsche Welle strives to achieve 0.5-1 mV/m, but says that its signals are sometimes as low as 0.1 mV/m. This is a level of 40 dBu (40 dB above 1 microvolt/meter).

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(14) "Technical Standards," Memorandum from Anna L. Case (VOA/EF) to William H. Read, May 3, 1982.

Ground-wave jamming propagates only in the vicinity of the transmitter, in a manner similar to MF or TV broadcast signals. It thus has the advantage of short distances from the transmitter, but the signal rapidly loses strength through absorption of energy by the ground. None-the-less, signal strengths much stronger than sky-wave signals can be generated in a local area tens of miles in radius. The possibility of breaking through such jamming in metropolitan Soviet-bloc areas having numerous ground-wave jammers is not very great, even with skywave broadcast signals stronger than VOA can now deliver. The Soviets would have to make an enormous effort, however, to "protect" their entire population with ground-wave jammers because of the large areas involved. Thus large parts of their populace will be subject only to sky-wave jamming.

The best solution to ground-wave jamming lies at the receiver: very selective (narrow pass band) tuning, radio frequency gain control to prevent overloading by strong signals, adjustable rejection filters, etc. (features not often available in present mass-market receivers); and use of directional antennas. In the latter regard, Professor O. G. Villard, Jr. of Stanford University has informed us that he has just devised and tested an antenna that will selectively discriminate against ground-wave signals in favor of sky-wave signals. This uses the phenomenom that signals of any initial polarization become vertically polarized as they travel outward from the transmitter along the ground. (In fact, a true ground-wave signal is vertically polarized.) HF signals reflected from the ionosphere, however, almost always contain components of either polarization, no matter what the polarization at the transmitter. Thus it is possible to build an antenna insensitive to vertically-polarized energy (e.g., ground-wave jamming), while maintaining full sensitivity to downcoming skywave signals. Prof. Villard said that he has made trials of an experimental antenna on the Citizens Band (27 MHz). The results were that local signals were reduced by roughly 20 dB, but distant (skip) signals from sources hundreds of miles away were reduced hardly at all. Further development would undoubtedly give even better results.

The antenna is basically a horizontal loop mounted about a foot above a ground plane, and can be as small as five feet in diameter. In construction, it is a scaled-up-in-size "conformal microstrip" antenna of the type recently developed for applications at microwave frequencies.

Professor Villard feels that the approach may have real promise for anti-jamming use, and plans to bring it to VOA's attention in the near future. How VOA might make use of such an antenna is discussed in the next section.

B. RECEIVERS

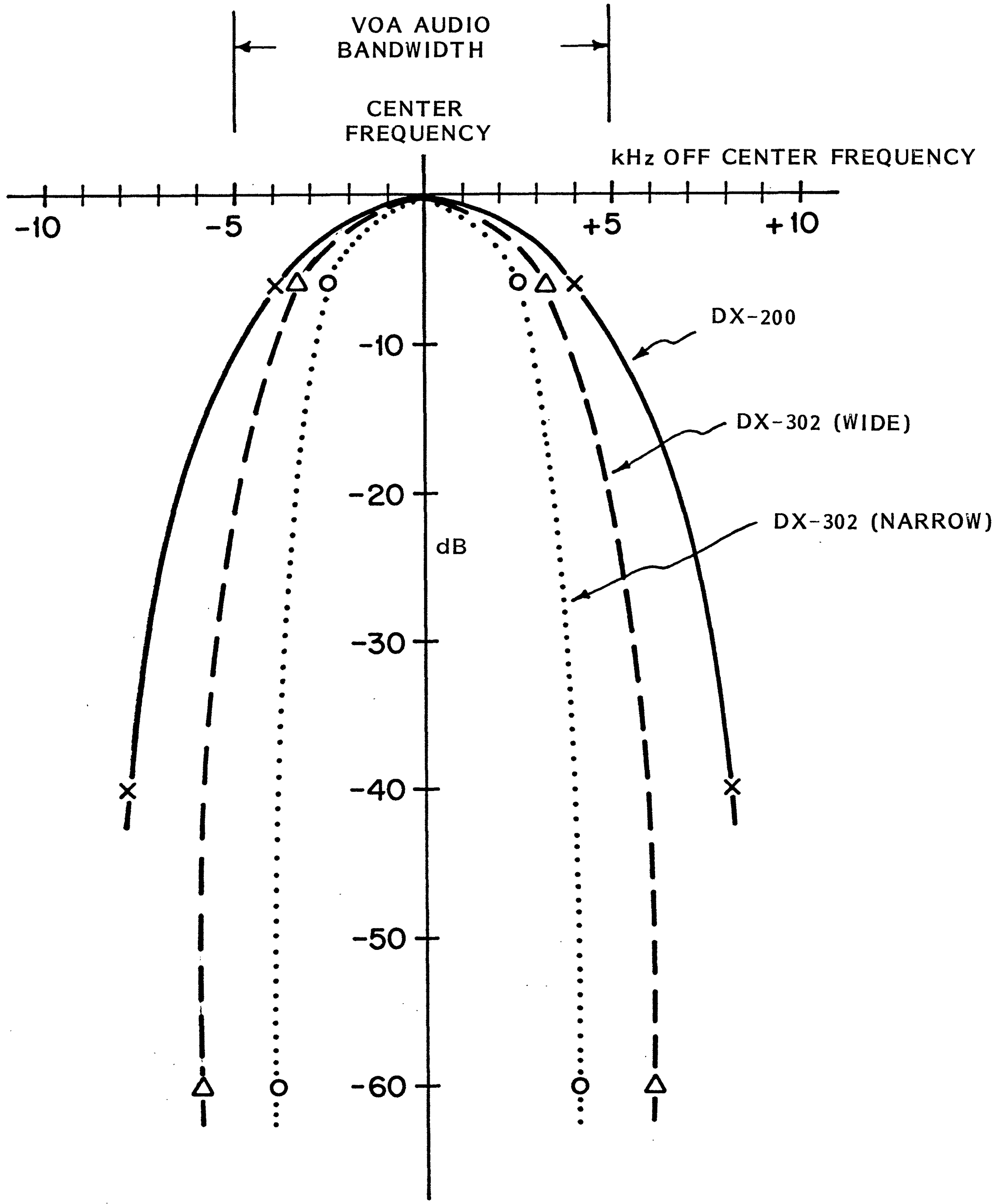
Most suggestions for delivering stronger and higher-quality HF broadcast signals necessarily address transmission alternatives. While the U. S. Government may control the number and kind of transmitters it builds, it cannot control the receivers the audience uses. But it would be a mistake to assume that the kind people use is a given factor for all time. While we must avoid wishful thinking, i.e., designing transmission systems for receivers and antennas that are not there, it is equally a mistake to neglect the substantial margin of influence the U.S. can have on the kinds of receiving equipment people around the world may be buying five years or more from now.

Present HF receivers are expensive and somewhat complicated to use. Information on antenna use and construction is generally in the province of the radio aficionado, as is access to programming data. Shortwave receivers for the popular market range in price from about $50 for handheld, insensitive, limited-band portables that will receive only strong signals having minimal adjacent-channel interference, to hundreds of dollars for more capable all-band versions. Professional models are priced into the thousands of dollars. Clearly, even the lowest price range is out of the grasp of many third-world households. These costs act as a limitation on HF listening. Also, as high-priced equipment, some HF receivers are sold as consumer packages with portable stereo tape decks and FM radios, carrying with them their own competition for the shortwave listening audience. And at the price range of a good shortwave receiver, many of the emerging affluent will opt for a television receiver before buying a shortwave receiver.

Medium-wave (AM) and some FM radios, on the other hand, are inexpensive enough for even many poorer listeners. Even good-quality television receivers are relatively equal in cost to a good shortwave radio, and the used market for television receivers is much larger than for HF radios. What is needed is a shortwave receiver in the AM/FM price range which also is effective in capturing weak signals in the cluttered HF bands with reasonable sound fidelity. This may be a contradiction, but some effort should be made to define the problem more clearly.

The main reason that good shortwave receivers are presently expensive has to do with the circuitry necessary to select from among strong signals having much smaller frequency separations than occur in the AM and FM broadcast bands. In the ITU HF broadcast scheduling process, stations may choose frequencies at 5-kHz intervals, thus the $\pm$5-kHz modulation sidebands of adjacent-channel stations actually overlap. While such frequency assignments are normally geographically separated to minimize interference, the long reach of HF signals via ionospheric propagation means that a listener trying to hear a particular signal often finds that it is sandwiched between interfering signals that may be of equal or greater strength, and insufficiently separated in frequency to be excluded by the normal ±5-kHz receiver passband. The better, medium-price HF receivers thus are designed with narrower passbands -- ±2.5 kHz being typical. The high-priced professional receivers have a number of selectable bandwidths (down to as little as 0.5 kHz for code reception), and may also have tuneable interference rejection (notch) filters.

Figure 2 illustrates the passbands of two typical popular-price HF receivers sold by the Tandy Corporation under the Realistic label. The DX-200 model ($299) has a signal rejection of 6 dB (2:1) at 4 kHz off-frequency, whereas the more expensive DX-302 model ($399) has selectable rejections of either 12 dB (4:1) or 60 dB (1000:1) at the same offset frequency. Although the narrowest passband of the DX-302 will effectively eliminate all audio frequencies above about 3 kHz, limiting fidelity to somewhat less than that of a telephone circuit, it will permit understanding of a broadcast that would be badly garbled by adjacent-channel signals if the passband were as wide as that of the less-expensive DX-200 model.



DX-200 -- 150 kHz to 30 MHz, Dial Tuning, $229

DX-302 -- 10 kHz to 30 MHz, Digital Tuning, $399

Fig. 2 Selectivity Curves for Shortwave Receivers Sold by the Radio Shack Corporation (Realistic Label)

In addition to a high degree of selectivity, other needed attributes of good HF receivers are a better sensitivity than is required for AM/FM receivers, more precise tuning control, and better frequency stability (the latter two are necessitated by the narrow passbands). All of these have been made easier to achieve with the new-technology developments of the past few years (digital frequency synthesis, SAW filters, microprocessor control, etc.), but to date these have appeared only in receivers priced at $400 and upwards. The U. S. Government could sponsor research and development for the design of superior shortwave radios that could be economically produced, along the recent model of the F.C.C.'s funding of research on improved UHF television tuners. This could be a major influence on the development of international broadcasting, would enhance the nation's and VOA's image and credibility worldwide, and might even spin off a U.S.-based manufacturing industry for shortwave receivers.

Another effort with a potentially high payback for international broadcasting might be to develop inexpensive antennas optimized for certain bands, or HF channels. Highly directional antennas (and, for some areas subject to jamming, with a sharp null capability) would aid in receiving signals in areas of weak field strength; perhaps these could be made to rotate, or some system of phased reception used for non-movable direction changing, to compensate for their size. In urbanized areas, or even villages, community antennas may be a viable alternative. It may be that such antennas could be constructed from inexpensive materials locally available, and VOA could distribute a set of instructions, or a simple-to-assemble kit. It may be cost-effective for such items to be distributed free or under subsidization by the U.S. Government; perhaps even the inexpensive radios could be so disseminated. This could be a more effective use of Federal funds than investment in transmitter equipment.

The possibilities for selling or otherwise distributing improved reception equipment in the USSR and Soviet-bloc countries are, of course, quite limited, but dissemination of construction information by various means may be feasible. Examination of several 1982 issues of the Soviet popular magazine Radio indicates that there is a broad-based capability for home construction of quite sophisticated radio equipment. The issues contain, for example, detailed plans and instructions for construction of antennas and receivers for television (48-610 MHz) and satellite (1215 MHz) signals. Information about the HF antenna being developed by Professor Villard that discriminates against ground-wave jamming (see preceding section) would be an obvious candidate in this regard.

There are some other options available to improve and increase shortwave listening. Manufacturers of HF receivers could be encouraged to take a leaf from the marketing of hi-fi and video components, and make available several add-on items that a listener buys as he can afford them. For example, attractive components now being introduced for the more affluent are video tape recorders with programmable, timer-controlled TV tuners that permit unattended recording, over periods as long as a week, of up to eight hours of desired TV programs for later viewing. Some of the current generation of videotape devices even make provisions for storing digital, stereo sound for similar lengths of time. Today, very few consumer radios with tape decks even come equipped with a clock, much less a programmable tuner.

Several very expensive, professional-model shortwave receivers having microprocessor-controlled tuning already have built-in timers and pre-programming capability. (15) We have not, however, seen or heard of any that make provision for automatic recording of pre-selected broadcasts for delayed listening. It would be a relatively simple matter in these receivers to add a recording capability; either the ability to control the recording of the selected programs on a separate audio cassette recorder, or to build in a cassette deck, as is now common in AM/FM portable radios. The challenge is to have this capability for at least medium-price HF receivers, and hopefully the inexpensive ones as well.

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(15) "WRTH Tests Premium Receivers," L. Magne, World Radio TV Handbook, BILLBOARD A.G., Vol. 36, 1982, pp 551-572.

Some sort of programmable recording capability like this for popular-price shortwave radios could improve the opportunities for HF in radio listening around the world. Its impact on international broadcasting could be striking where time zones and ionospheric variations make scheduling for live listening very difficult. We discuss a more long-range strategy for delayed HF broadcasting reception dealing with digital electronics in Section IV-B-3.

C. POLITICAL ISSUES.

The quality of signal to which people will listen is a function of their motivation. If they are listening for recreation they will choose VOA only if the signal is good. If they are listening in intense fear in a major crisis, they will struggle to decipher the words in very poor signals. Year in and year out, however, VOA will have little impact without a good signal.

VOA has an investment of about one billion dollars in 16 sites around the world for transmission, and for relaying of HF and some MW signals. These sites have been an optimized compromise between engineering considerations and political requirements. Some critical areas of the world have yet to be serviced, and VOA has embarked on a construction program to alleviate these deficiencies as well as possible.

REDUNDANCY

The simple fact about site planning is that all the overseas sites are vulnerable to political changes, and all the sites are somewhat vulnerable to sabotage. The former problem can only be mediated through negotiation with host countries, usually at some monetary and political cost. Both problems are substantially reduced if VOA has back-up transmission sites, redundant and steerable relay facilities, and a set of workable contingency plans. Even satellite transmission -- for relaying or direct broadcast -- is not a perfect panacea since somewhere a ground station is necessary. Also, while satellites are much freer from political and sabotage threats than ground facilities, they are not invulnerable to determined physical attack by a major power having both the desire and the means to do so.

This means that standby capacity has to be kept in working order at some cost greater than in a no-risk environment such as faced by ordinary commercial broadcasters. Admittedly, during times of budget constraint, this is a difficult cost to justify, but it must be approached from the point of national security, not from a direct broadcasting benefit-cost viewpoint. And, maintaining such redundant facilities means more than a capital investment in mothballed equipment; the facilities must be used in some meaningful and regular fashion so that experience is maintained by personnel, bugs are ironed out, and flexibility to crisis responses is kept in readiness. That is not a simple logistical task.

RELAY SITES

Given America's location, oceans away from audiences in Europe, Asia or Africa, direct short wave broadcasting from U.S. territory requires very high-power transmitters; these are bound to be limited in number because of cost. Also, as we have noted in Section II-B, reception would not be very good because of propagation difficulties. None-the-less, we must face the reality that relay sites in other countries may be denied us at any time, and in a period of tension, with short notice. It is obviously important to the U.S. to have some such transmitters to reach very high priority audiences in the Eastern hemisphere, as well as audiences in the Western hemisphere.

We do not base our case on the argument of pessimists who for years have been saying that the overseas relay sites were likely to be closed down. On the whole, friendly countries are willing to allow rental of retransmission sites for reciprocal considerations in money or favors. Among the favors are the ability to use the sites for their own broadcasting during certain hours when we are not using them. There are some countries that see leasing of real estate for transmission purposes as a good business and are willing to lease to any country without political preference. However, one should not underestimate the risk involved in reliance on overseas retransmission sites and the difficulty of getting them in desirable locations.

For one thing, like a military base, a transmitter site is a hostage to changing political climates. It is a large investment and, once it is in place, getting rights renewed and leases renegotiated puts this country in a position where there is something we want badly and for which we may have to bargain. It is, therefore, desirable to always have an alternative that our opposite numbers know about, even if it is not quite as good as the desired remote relay site. Besides that, we must take account of the possible sudden loss of an important site, either by revolution, war, or panic of the host country in a crisis.

None-the-less, having a substantial number of well distributed relay sites of great importance. They permit medium wave broadcasting along with short wave. This is very important right now in the Middle East and for Eastern Europe. Also, more relay sites permit broadcasting from a variety of directions to jammed areas, greatly increasing the odds that some of the transmissions will get through. Relying to any important extent on transmissions from the Western Hemisphere would be a serious mistake.

We have discussed some technical issues involved in having a large number of diverse transmission sites in Sections II-A and II-B. These issues include the possibility and desirability of low-manned or unmanned stations, the trade off of numerous small transmitters vs. a few very large ones, and the possibility (unfortunately not great) of transmission from other points on the compass.

The best strategy for VOA to pursue might be a mix of redundant transmitters, including high-powered facilities on U.S. territory, redundant feeders with backup, pre-recorded programming, and continuing involvement of the host countries in some aspect of VOA operations or facilities so that some community of interest is fostered in maintaining VOA continuity. This latter point will be discussed later in some longer-term political concepts for the evolution of international broadcasting.

Since retransmission sites and frequencies for international broadcasting are important for this country, those who have responsibility for negotiating leases for transmitter sites abroad and frequencies in the ITU must appreciate the high priority that these have for the country. In a situation in which foreign relations are very multi-dimensional, too often we find transmitter site negotiators and U.S. representatives at radio conferences failing to give adequate weight to the importance of broadcasting facilities for this country. This is not surprising. Those who conduct such negotiations cannot be specialists. They will give full weight to VOA needs only if their instructions from top levels so require.

III. JAMMING

As long as jamming continues, there is no panacea for overcoming it. Although there are technical ways to reduce its effectiveness, and to make it more expensive and unattractive to the USSR to maintain a given level of "protection" for its citizens, many Soviet listeners will still be unable to hear foreign broadcasts that their government does not want them to listen to. Political means to encourage the Soviets to reduce or conceivably eliminate jamming would be a better solution.

Jamming is not costless to the USSR. In terms of manpower, equipment, and electrical power, they probably spend more to jam than the broadcasters do to transmit the programs they are jamming, and there are also other costs. Unless they are very careful, it creates noise and interference with their own programming, annoys their own population, and hurts their credibility at home and abroad. It also creates interference far across the Soviet frontiers, thus bothering other broadcasters besides the ones they wish to jam, and alienating listeners over a wide area of the world. But the Soviet regime is so intensely fearful of the diffusion of information to their population that there is no reason to expect them to abandon jamming completely, no matter what the cost of keeping it up, until there have been major changes in the overall world situation.

In Section II-B-6, we discussed the extent to which American transmissions can be given greater effectiveness in penetrating jamming. This can be done, in part by increasing the radiated power of U.S. transmitters, but even more effective than that, it can be done by increasing the number of different beams coming from different locations and by controlling the focusing of those beams. As was noted in Section II-B, getting improved reception equipment into the hands of listeners would also be of great help if this could be effected to any great extent.

But purely technical fixes at best only somewhat ameliorate the jamming problem and increase the incentives for the Soviet to consider a less tractable position. The question remains as to whether there may be political ways to persuade the Soviets to abandon or reduce jamming.

Our informants were not optimistic on this score. In general, the feeling was that it will be difficult to negotiate more permissive policies with the Soviet government unless they perceive some prospect of reciprocity. One person interviewed was quite emphatic that countries outside the Soviet bloc will get nowhere by simply demanding that jamming be stopped; and that they must therefore have a bargaining point, i.e., something in the full range of inter-government relations that is of value to the Soviets and that can be given up, if necessary, to gain access to Soviet-bloc listeners. He felt that if the U.S. government really wants jamming stopped, or at least reduced, that it should first identify one or more such bargaining points, enlist the aid of as many countries as possible, and then enter serious negotiations.

The prospect of improved penetration by American broadcasts, even if in ways that could eventually be overtaken by greater Soviet efforts at jamming, may therefore be of substantial value. For example, if we can show our determination to raise the cost to the Soviets of jamming sufficiently by a well-developed plan to increase the number and the strength of beams directed at the USSR, they may be willing to back off on jamming. Or the possible tradeoff may be in some other area of dispute between the U.S. and the USSR.

It is neither hopeless nor easy to get other countries to help us persuade the Soviets to refrain from their present illegal efforts at jamming foreign broadcasts. It is not a high priority matter for most countries. Relatively few of the ones that are doing international broadcasting regard the Soviet population as a priority audience; more often they are anxious to reach their immediate neighbors in their own region. Furthermore it is not always clear to most listeners and politicians in the areas of the world not adjacent to the USSR that the noise heard on shortwave bands is from Soviet jamming equipment. If they think about jamming at all, they are likely to think that this is simply a squabble among the superpowers. Only their technicians are likely to realize that the Soviet jamming is in fact polluting the shortwave spectrum throughout much of the world and depriving other countries, including Third World countries, of the possibility of broadcasting cheaply and easily.

The U.S. in its communication efforts should seek to familiarize political leaders as well as technical people in other countries with the fact that about 50 percent of the worlds HF broadcast spectrum is being made unusable by Soviet jamming, as we pointed out in Sections II-A-6 and II-B-6.

IV. FUTURE POSSIBILITIES

As television and recorded audio/video material replace radio as the normal leisure time activity, as cable systems become widespread, and as direct satellite broadcasting comes into use, the methods by which international communications take place will change significantly. While the improvement of its conventional short wave transmission capability should be the prime objective for the next few years, now is also the time VOA should start planning for future alternatives, for several reasons:

1) To gain a greater share of the international audience, with a marginal investment, by exploiting other media to deliver its existing audio programming.

2) To develop new audiences among groups important to United States foreign policy who today are not attuned to HF broadcasting for information, or who are not even oriented to the audio medium.

3) As a contingency backup in the event of a partial or complete blackout of HF spectrum due to jamming or coordinated attacks on VOA's physical broadcast plant and feeds.

4) In preparation for the emergence of new modes of international communications that may displace HF listening in the course of the communications revolution.

There are many possible technological alternatives for "broadcasting" to present and new audiences, and in different media, though each technology will have its own level of costs, complexity and difficulties. These problems and opportunities must be weighed against the conventional HF mode to determine if the effects of substitution or reinforcement are justifiable. We divide the alternatives into short-range possibilities available within the decade, and longer-range potential technologies, which by their very nature require more detailed strategic planning, and are more problematical in their effects and availability. In the latter case, as we have noted, U.S. policy initiatives could be instrumental in bringing new media into general use, affecting how they are used, and their audience. The possibilities presented here are:

A. Short Term

1. Local Delivery Systems
2. Cassette Tape Systems

B. Preparing for the Long-Term Future

1. Advanced Systems
2. Digital Storage
3. Advanced Microprocessor and Timer-Tuner Sets
4. Direct Satellite Broadcasting
5. An International Common Carrier

A. SHORT TERM

1. LOCAL AUDIO DELIVERY SYSTEMS.

In this category we include standard FM, Medium Wave, and the audio channels potentially available in cable television systems. FM and CATV will be of growing influence in urbanized regions in many foreign countries. Already, U.S. satellite feeds are being tapped by Caribbean and Central American cities for private CATV systems feeding hotels and residential complexes; this pattern can be expected to expand. VOA should consider various alternatives of distributing programming on these outlets.

One possibility could be to provide programming via satellite or tape to local originators. There is a large increase in the demand for both radio and TV programming in many countries. When CATV is introduced, new channels need to be filled; some of this programming could be VOA audio. In many countries local and private radio stations are increasing in number. System owners will be seeking material to fill channels; they may even buy material. On the other hand, in other places artificial constraints may be introduced to keep scarcity of channels at a level where VOA might have to buy or negotiate for access. Extensive increase of local broadcasting channels and the wiring of urban areas for audio or video will otherwise tend to dilute VOA's HF audience by providing the listeners with increased alternatives. VOA must respond to this situation by providing its material to such new systems. In any case, increased efforts should be put into distribution of audio and videotapes to broadcasters and cablecasters, and also into direct feeds to them for re-distribution. (16)

It should be noted that the BBC already has established itself in the U.S. television market by providing pay-video on cable/satellite outlets, and by providing its audio news broadcasts, via satellite and delayed taping, to National Public Radio. If nothing else, this has increased the BBC's audience in the U.S. by a quantum jump as well as delivering its signal with greater fidelity and strength than via HF broadcasting direct from London or via its relay in Nassau. *

(16) See National Public Radio, Listening to the Future: Cable Audio in the 80s (1982); and Pool and Solomon, "The Future of Audio Broadcasting in the United States", Telecommunications Policy, September 1981.

* RFE/RL is negotiating with Belgian CATV for use of some of their material for audio broadcasting.

2. CASSETTE TAPE SYSTEMS.

There has been an enormous expansion in the availability and use of cassette audiotapes in recent years. Recorders are pervasive throughout the world, even in developing countries; indeed, even the Iranian revolution has been partly ascribed to their use. VOA already makes its programming available to other broadcasters, educational outlets, and others via tape and cassette. It should be recognized that storage media, such as digital tape and memory chips, are undergoing a revolution as radical as that found in other area of communications which in the next five years may make audio cassettes an important outlet for VOA, both for broadcast and for the public directly.

B. PREPARING FOR THE LONG-TERM FUTURE.

In the past, VOA's audience has been relatively easy to pinpoint, though in some cases extremely difficult to reach. But in coming decades the precise audiences to be reached will become difficult to predict as world conditions move from one crisis to the next. This is all the more reason for VOA to remain fluid in its use of technology, and in maintaining as broad a base of broadcast facilities as it can muster. For most of its existence VOA has had two important audiences: the Third World and the Soviet bloc. In both of these, for different reasons, domestic news media serve their publics inadequately. The principal content of VOA has been news, education and to some extent efforts to counter disinformation from non-friendly countries. In addition, a third general audience now requires VOA's attention: both in our Allied nations, and in developing, neutral, and oil-rich nations, there are large and growing sophisticated technological elites whose attitudes affect this country greatly, and who will seek out high-quality information services.

The importance of all of these audiences and these goals are growing for HF broadcasters, but more important, modern electronic communications techniques have begun to outstrip the capabilities of conventional short-wave broadcasting in delivering these messages.

1. ADVANCED SYSTEMS.

While cable television gets most of the attention, other types of wireline technology for audio must be considered since audio could be relatively simple to piggyback on other systems such as digital telephone and video networks. (18) This is an opportunity for audio where those cable systems offering this service have tended simply to rebroadcast standard FM stations for pickup on FM tuners. With proper lead-time, VOA could help orient the evolution of such complex, integrated service in some regions. There are no accepted national, not to mention international, equipment standards for such systems as yet, but intensive efforts are under way to create such standards.

New devices will be designed and marketed which may permit access to hundreds of wireline audio channels. These devices may also be able to access data and text similar to an idea we discuss later in this section for novel HF receiver technology. National Public Radio is beginning an experiment using the FM subcarriers on some of their outlets with some of these features which will permit the subscriber to program audio programs in advance.

(18) National Public Radio, ibid., and Pool & Solomon, ibid.

Such developments are likely to occur first in the United States, Western Europe and Japan. Encouraging their subsequent adoption elsewhere not only facilitates the free flow of information, but also may offer markets for American equipment manufacturers. A variation of these ideas is to use the audio portion of UHF television channels for delivery of radio programs where channel space is available. One possibility is to deliver the signal directly from satellites, as will be discussed under DSB in Section IV-B-4; another is to subdivide one or two UHF video channels for audio. Thirty or forty FM, high-fidelity signals could be transmitted on an 8 megahertz television channel, the standard for most of the world other than the U. S. and Japan. With lower fidelity, one hundred or more audio channels would be possible. Though new equipment would be required, and this concept transcends the short-range potential, it could be worth keeping in mind at the next WARC and RARC international conferences concerned with UHF and video spectrum.

2. DIGITAL STORAGE.

Digital storage techniques are permitting cost reductions for duplication and higher quality sound. Use of videodisks and videotape for audio or mixed audio and animated stills is another possibility. Videodisks hold much promise for educational programming because of the inherent cababilities of random access and cheap reproduction, as well as their virtual indestructibility. Standards for these systems are one obstacle to their current widespread use; VOA may be able to help resolve such issues by getting involved in their use and in developing worldwide standards during this formative period. Another similar technology may be the forthcoming digital audio disks which holds even greater promise for inexpensive quality reproduction of sound.

Such storage media will not be able to replace VOA's timely news service, but variations could be a supplement to such activities. The VOA telecommunications net could be used to reproduce such media remotely and perhaps with some degree of timeliness.

3. ADVANCED MICROPROCESSOR AND TIMER-TUNER SETS.

Described below are a number of ideas that might be termed "far out," but are still within the realm of possibilities. We do not suggest any short-run commitment to any such far-out ideas. We raise them because the VOA planning personnel should be actively aware of all these possibilities (and others mentioned elsewhere herein) so as to ensure that as appropriate situations arise they are prepared to take advantage of them, and also so that they can speak up for VOA needs in U.S. Government planning and R&D activities.

Because of the large bandwidth required for full motion video and the political views held by many governments, we do not anticipate that the strong resistance to international direct television broadcasts will be overcome soon to the extent that will allow a TV-DSB-VOA. However, some consideration should be given to the possibility of narrower bandwidth being available for still-frame video use in international broadcasting.

We discussed the possibility for combining timers with tuners, as is now done with video tape recorders in Section II-B, "Receivers". However, these concepts could be extended during the long-term towards other non-conventional concepts for receiver technology.

For instance, in the longer-term future, it may be possible to combine the demand for stereo cassette portables or for television component systems with a special radio tuner capable of receiving intercontinental signals. The portion of the spectrum to be used may not even be in the HF band, but perhaps in the UHF band, with signals transmitted from satellites. If such transmissions include visuals as well as audio, this could be part of international videotext transmissions, making maximum use of an enhanced television receiver. VOA may well be able to stimulate use of such new technologies, if it coordinates with consumer electronics manufacturers, and with our allies in international broadcasting.

While the short-term strategy for enhanced listening might be to encourage programmable timers on short-wave cassette tape decks as we note in Section II-B, our imagination should not stop there. Low-cost digital storage devices and programmable, pre-tuned digital tuners could be developed using VLSI microprocessor technology. Such a device would be flexible enough to capture transmissions at optimum times for later playback at the listeners' convenience. Eventually, these devices might cost less than current videotape/audio devices, and less than the cost of portable stereo tape decks.

Intelligent devices could receive coded textual information for display on video screens in different languages. The teaching potential of such a method of delivering information would be very great. Also digital broadcasting, or some other appropriate modulation scheme which does not interfere with existing uses could be introduced as part of these new standards. There already are European plans for new enhanced video transmission, including four-channel digital audio, in connection with the direct-broadcast satellites to be launched in the next few years. If VOA helped set the technical standards for such novel international telecommunications systems the United States could have an enormous advantage in the long-run.

4. DIRECT SATELLITE BROADCASTING

The most important long-run possibility for VOA is satellite broadcasting of radio signals direct to home receivers (radio-DSB). The importance of planning for this now is that the decisions made in the ITU's World Administrative Radio Conferences during next few years will determine whether or not international radio satellite broadcasting will be permitted during perhaps the next quarter of a century. It is essential that U.S. government delegations to those conferences know what it is that our broadcasters will want to do.

The 26-MHz band has been considered for radio-DSB use in several recent studies because it is already allocated for international broadcasting, is underutilized, and is at a high enough frequency that space antennas, while necessarily quite large, seem feasible. (19) There is a problem, however, of a lack of 26-MHz receivers in place worldwide, as will be discussed in Section V-3. As long as new receivers are going to have to be obtained by listeners for radio-DSB, they could just as well be for other frequencies.

(19) Rogers, T. F., "Modernizing and Expanding International High-Frequency Broadcasting," privately circulated paper, January, 1982; also Phillips, G. J., and Knight, P., "Use of the 26-MHz Band for Satellite Broadcasting," E.B.U. Review-Technical Part, August, 1978, pp. 173-178.

A proposal that has been made in ITU discussions, and supported by a number of Third World countries, would create a new and very valuable channel of international communication. That proposal is that some bands of UHF be allocated to satellite broadcasting. Most of the use would certainly be for TV, and that is almost bound to be largely national and largely redistribution. TV uses so much bandwidth that the number of UHF satellite TV channels would be small, and in general they would be used up by countries wishing to beam programming to their own territory. While the United States rightly refuses to agree to any principle of prior consent for satellite TV, practicalities make it unlikely that many clear channels would exist for it. Radio broadcasting is another story. If some of the UHF Direct Satellite Broadcasting (DSB) spectrum were used for radio rather than TV, 50 to 100 radio channels could easily be made available.

The advantages of UHF for direct broadcasting are very great in terms of satellite construction, compared to lower frequencies. New receivers would, of course, have to be acquired by listeners, but these could be quite inexpensive (many low-cost portable radios already have the capability of tuning the FM-audio channels of TV stations). A conventional TV antenna positioned vertically might do, and these could be priced as little as $25.

From a technical point of view, radio direct satellite broadcasting appears to be a feasible and very desirable new medium of international communication, whether at HF or UHF. The real problems are in the political arena and in marketing, as described below.

The first requirement is political; the system has to be made attractive to many nations so that the ITU will allocate the needed frequencies. If a large number of nations wish to establish such a system of broadcasting, the pattern at WARCs is to accommodate them; if just the United States and a handful of other advanced countries desire it, the chances of getting such an allocation would be small. It is therefore necessary to design the system so that it meets the needs and interests of many countries.

Secondly, the system has to be attractive to millions of listeners who have to invest in the new equipment, just as they have now invested in short wave sets. There clearly are hundreds of millions of persons who find listening to foreign broadcasts worth an investment of something like $50 to $150 (or more) for conventional HF receivers. But the number who would make an investment in new equipment that would permit them to listen to just one broadcaster, the VOA, is much smaller, even if the investment were nominal (say $30 to $40). The system being created has to be one that carries a great variety of broadcasting from different countries and of different content. Listeners want music, education, drama, as well as news. They like to listen to a variety of exotic far away places. They want to hear different viewpoints. In short, the successor to the short wave bands must be as rich and varied in content as short wave is today, if not more so.

The problem that the United States faces in maintaining an effective international voice in the satellite era that will follow the present short wave era is to take the lead in meeting a widely felt and internationally shared need. In the contemporary world with large numbers of intensely nationalist and repressive regimes, that will not be easy. Indeed one can surmise that if the present system of short wave international broadcasting, in which so many countries are now engaged, were not in existence and were presented to an international conference as a new idea, it might well be rejected. Building towards the maintenance of such international communications in a technologically different future will take substantial imagination.

Specifically, there is the problem that even 50 or 100 radio channels is not a very large number. Actually this number is effectively larger than it appears because, with shaped beams, the same frequencies can be reused in separate locations. Fifty channels in any one location is a large number. Still, in the

21st century, one can anticipate that there will be a much larger number of broadcasters who will want to be heard. Channel sharing of some kind will certainly be necessary. Perhaps the optimal scheme is some sort of common carriage that assures every would-be broadcaster the opportunity to lease time for his transmissions. This could be done by an international organization analogous to Intelsat. It could be done by an international commercial carrier, which we discuss in Section IV-B-5. It could be done by a U.S.-launched satellite system that made time available to all comers or by a co-operative launch. It could be done by an inter-governmental scheme. From the U.S. point of view the only essential requirement is that we be able to lease time to broadcast our programs, uncensored and unregulated. We should be delighted to have the same opportunity made available to others.

With that kind of system, there is good reason to believe that a smooth and gradual transition could be made from the present system of short wave broadcasting to a more advanced, more widespread, higher quality and less jammable system of satellite broadcasting, and one which should cost less for broadcasters. Technically, the space segment could be designed now for service in a few years, but first the necessary agreements and frequency assignments have to be negotiated, which could take five to ten years. Then there will be a transition period as programmers come on line and receivers get purchased over another five or ten years. That may seem too long a period to worry about now. However, there are some things that must be done now if we are to avoid finding ourselves cut off from this technological prospect. Most important is that the government agencies involved in international communications issues reach a clear understanding of where we want to go, so that as issues come up about spectrum allocation, or Intelsat policies or similar matters, we press for those decisions that keep the options open. At the same time, we should do what we can to help other countries realize how their objectives and activities can be served economically and well by such an international system.

5. AN INTERNATIONAL COMMON CARRIER.

International broadcasting, as a medium, is more than the sum of the individual broadcasters. People who would not bother to listen to VOA alone may become enthusiastic listeners to the great international debate that takes place on short wave if they could hear such programs reliably with good quality and at low cost. They would enjoy hearing all the points of view and enjoy hearing from different parts of the world, and their enjoyment and appreciation of VOA would be heightened by comparison, cross-checking and contrast.

This suggests that as we think about communications services and systems for the long range future, we not think about VOA in isolation, but think about what sort of international forum can be created for the 21st Century that will enable people around the world to hear the variety of views and interpretations that will exist. The American view will come out well in such a forum, as it always has.

We, therefore, strongly suggest that in considering satellite systems or other advanced communications systems, this country give substantial attention to the possibility of the development of international broadcasting common carriers.

There are many countries that cannot themselves afford a major effort at international communication. In addition to the 26 countries with superpower transmitters there are another 100 broadcasting countries which do not have them, and many cannot afford them. A common carrier system that would allow all countries an opportunity to broadcast some material would have a wide attractiveness.

Furthermore it could be a private enterprise activity at least in part. Intelsat, which is in fact operated by the profit-making Comsat, is one possible model. Or conceivably it could be a set of competing carriers. It could lease time to private as well as governmental broadcasters. In any case, the important point for the United States is that we be able to buy as much broadcasting time as we wish, and that many other broadcasters also be on the system, giving it interest, diversity, and credibility.

One can expect that if the United States announced its intent to prompt the creation of a common carrier satellite broadcasting system/service that all nations might use, there would be substantial expression of both welcome and opposition, but hopefully, the presentation of such an idea would lead to consideration of how to internationalize the effort to create such a global instrument of communications.

V. REACHING THE AUDIENCE

The underlying problem to which this report pertains is how VOA can reach its potential audiences. There are a number of barriers that can stand in the way of success. Poor programming can lose audience interest. Poor transmission can make the signals inaudible. Use of frequencies for which sets are not available precludes listening. Expensive receivers cannot be purchased by many. Deliberate interference can disrupt reception.

Outside of the United States there are over one billion adults in the world who have access to short wave radio sets. (20) All of the world's major powers and many of the minor ones are seeking to reach them. As of April, 22 nations were transmitting with a total of 93 500-KW transmitters; 31 more such high power transmitters are under construction, bringing the total to 26 nations using 124 superpower transmitters to get their messages to the billion listeners.

The United States is not the leader in this competition. The Soviet Union has 29 500-kW transmitters with eight more under construction. West Germany has nine such transmitters, France

(20) Gifford D. Malone, Interim Report on Radio Waveband Coverage, June 7, 1982.

has eight with three more under construction, and the UK has two with six more under construction. The United States has six such superpower transmitters (or to be precise 12 250-kW transmitters which can be combined in pairs to achieve the result of six at 500kW). These, however, are at Greenville, North Carolina, much farther from VOA's overseas audience than the superpower transmitters of other nations. Countries like Gabon and Libya have four superpower transmitters each.

In addition to the short wave competition which is becoming more and more intense, the Voice of America, like other international broadcasters, tries to reach certain audiences by standard medium wave (AM) broadcasts where it is possible to site transmitters in close proximity to them. Here again the United States is at a disadvantage, but this time not one of our own making. We are separated from most of the audiences that we wish to reach by wide oceans. Our only present use of medium wave, for example, is to broadcast from Florida and Antigua to the Caribbean, from Greece to the Middle East, from West Germany to some parts of Eastern Europe, and from Bangkok and Botswana to those local areas.

The U.S. needs to expand such activities wherever it can. It cannot, however, hope to rival in volume the AM broadcasts by other countries to their near neighbors because there are no available, unused frequency allocations in some of the most important areas of the World, particularly in Europe. Given this constraint and our geography, short wave broadcasting and new methods of communication such as radio-DSB and wide distribution of tape cassettes are of primary importance.

Fortunately, the job of bringing to the world's population a better understanding of our national goals and the realities of the interplay in world politics, is not that of VOA alone. The effectiveness of VOA depends not only on its own reliability and accuracy, but also on being part of a large flow of information which confirms and makes meaningful what VOA says. The short wave listening audience hears propaganda claims from the Communist sources and from their own often unreliable governments. It turns to VOA, BBC, RFE/RL, and other broadcasters to clarify what lies behind the unreliable reports from the distrusted sources. And it turns to other broadcasters to validate what they hear on VOA. International broadcasting is thus of a piece; the whole is more than the sum of the parts. Our allied and other friendly broadcasters are more than just competitors for the audience. They are part of making a lively, believable, interesting medium which helps VOA meaningful to its audience.

The paragraphs following discuss the importance of content, languages, and receivers as factors in reaching the audience.

1. CONTENT.

The content of programming is not the subject of this technical report. Yet it is necessary to note the fact that without credibility and interesting programming, nothing else will make a difference since the audience will not be there.

2. LANGUAGES.

Inadequate language coverage limits effectiveness. Unless we broadcast in languages that the target audience can understand, nothing else will make a difference. VOA and RFE/RL now broadcast in a total of 46 languages. The USSR broadcasts in 80. In the North Africa, Middle East and South Asian region, the contrast is even more striking: there the USSR broadcasts in 27 languages, while the U.S. is heard through the VOA only in 8 different languages. What is more, most of these broadcasts from our side are but a few hours a week. There are constraints in the programming budget and staff, and each additional language desk costs a substantial amount per year. But the limitations are also in the transmitters. There are a limited number of transmitters pointed to any given area of the earth. If a transmitter is broadcasting in one language it is not available at the same time to be broadcasting in another.

It is not within the terms of our study, nor our competence to suggest priorities in languages for broadcasting, but we do note that proper transmitter planning requires close attention to decisions about language priorities. That indeed is the way in which planning has been done in the past. VOA and NSC staffs have drafted lists of languages in ranked priority and have thus derived an estimate of what transmitters would be needed to cover them at the times required and from the places where relay sites could be located. This is proper procedure. If we have any reservations about what has been done, it is that to some degree the calculations have been done under time pressure in preparing for budget deadlines. We believe that it would be possible for a professional staff in the Chief Engineers Office (or a contract research organization) to develop a computerized planning model of languages and transmitters that would take account of time zones, geographical coordinates of transmitter beams and ethnic populations, and costs for extra language programming. We would like to see such a computerized planning model in the hands of VOA. This is one of a number of suggestions we make in section VI on management tools using computerized modelling to help solve some of the difficult technical decisions VOA engineering must make.

3. RECEIVERS.

If there is to be an audience, broadcasting must be done at frequencies and with technologies which will deliver the signal to the intended areas, and for which listeners have receiving sets. That is one reason why short wave (HF) broadcasting will remain important for at least the next couple of decades. There are an estimated 1.3 billion radio receivers in the world. Of the 800 million or so of these that are in countries other than the U.S., 40-70 percent have some HF bands, depending on the region. The Soviet bloc has about 160 million radios, with about half the adults having access to a set which can receive HF.

In contrast to short-wave access, about two-thirds of the adults in the world have access to a set which receives medium-wave (MF or, as we term it in North America, AM). It follows that where it is possible to reach audiences by medium wave it is very desirable to do so. Medium wave broadcasts, however, do not carry for very long distances, requiring transmitter siting close to the intended audience. Also, medium wave radio assignments are made for national use, and few assigned frequencies remain unused. Therefore, there may often be no way of broadcasting to a particular country by medium wave. The USSR has a very great advantage over the USA in this respect. Since Admiral Mahan's day, Russia has been called a "heartland." All along the Soviet southern and western borders from Vladivostok to the Baltic, a few hundred miles in, lies a ring of some 25 powerful medium wave transmitters which reach directly to all of Asia and Europe and much of Africa. Two-thirds of these are of one-megawatt power, the remainder are of 500-kW rating. On the other hand, the United States is on a perimeter, separated from most of its priority listening areas by wide oceans. Medium wave will not reach from the Continental U.S., except to audiences close to our southern border.

Where overseas sites are available, where audiences are in feasible range, and where frequencies for medium wave broadcasting exist, it is very important and should be given high priority. However, short wave (HF) broadcasting, which can go very long distances by reflection from the ionosphere will remain the most widely usable instrument for US broadcasting abroad.

Not all HF frequencies are equally receivable by existing sets. The bulk of short-wave receivers cover only the 6-, 7-, 9-, and 11-MHz bands. A smaller number also receive the 4-, 15-, 17-, and 21-Mhz bands, and an even smaller number cover the 26-MHz band. Standard sets in the USSR, we have noted, receive only up to 15 MHz. The 26-MHz band suffers from a sort of "chicken or the egg" situation. Since the 26-MHz band is near the upper limit of frequencies reflected by the ionosphere, it has much less reliable propagation characteristics than the lower bands, and has not, therefore, been attractive to broadcasters. This in turn has diminished maker and buyer interest in radio receivers for 26 MHz. (VOA has estimated that only about 10 percent of adults worldwide have access to a 26-MHz receiver, and much less than that in the USSR.) This relatively small receiver population has served to further reduce broadcaster interest because even when 26-MHz propagation conditions are right, there can only be a small audience. The current situation is that less than one-half percent of all HF broadcasts are made at 26 MHz.

As was discussed in Section IV-B-4, several recent proposals have suggested the 26-MHz band for radio Direct Satellite Broadcasting (DSB) use, but recognize that there would only be a small audience unless a large number of listeners acquire new receivers, or front-end converters for this band. Should UHF spectrum be allocated for radio-DSB, as discussed earlier, new receiving equipment will also be required.

The basic HF effort in the next few years clearly has to be in the other bands which have plenty of listeners and therefore, unfortunately, much overcrowding. New modes of broadcasting which require the listener to invest in new receiving equipment should not be dismissed for the long run, however. There will be changes in the world broadcasting system. Satellite broadcasting, for example, will certainly become a reality in due course. However, none of these systems can be a substitute for ground-based short wave transmitters except in a protracted process of gradual evolution. We have discussed some of these issues in greater detail in Sections II-B and IV-B.

VI. VOA MANAGEMENT ISSUES

A. TECHNICAL LETHARGY -- CAUSE AND EFFECT

It is quite obvious that VOA's internal capability to plan and execute new facilities probably peaked a number of years ago, as did its capability to operate its worldwide facilities on the most efficient basis. This is not to disparage those dedicated personnel that manage to keep the system going as well as they do, it is just that a number of factors beyond their control (or seemingly anyone's control) have combined to make it much more difficult to maintain the environment which fostered VOA's growth and operations in its "salad" days. To cite a few of these factors:

- inflation has affected VOA like almost any other government agency; wage scales and the costs of materials and services have risen faster than budgets, forcing cutbacks and staffing shortages in almost every department, and limiting capital expenditures for new or better labor-saving equipment (to some extent this is compounded by the next two items);

- VOA shares the staffing problem of most organizations that started or greatly expanded a generation ago: a large proportion of original staff members who are now nearing retirement age, with elevated salary scales compared to starting level, and not having had the benefit of formal education in the technology advances of the last 10-15 years in such important fields as computers, electronics, communications theory and practice, etc.;

- HF broadcasting technology is almost an anachronism to young U.S. engineers, with little glamor, few job opportunities outside the government, and little opportunity to become proficient in it even if they wanted to (radio engineering, once a forefront topic, has almost disappeared from college curricula), and the result is that it is very difficult for VOA to even find capable young engineers, much less interest them in hiring on at VOA.

- as with many government agencies, major capital acquisitions are a real trauma, with detailed scrutiny and "engineering" judgements by numerous watchdog boards and committees of the Administration and of the Congress, and even that equipment that is finally approved is expected by the budget makers to last forever and never need replacement, even if its effective half-life is only a few years in today's rapid pace of technological development;

- circumstances of the crowded office space situation for government agencies in Washington have maintained an awkward physical separation between the Office of Engineering and Technical Operations and the rest of the agency that tends to inhibit the close working relationship that is necessary between engineering and operations on the one hand, and policy and programming on the other;

- although VOA's mandate from the Congress specifies an objective and unbiased approach to programming, and this has been fairly well maintained over the years, the major and well-publicized turn-overs in top-level personnel in the last few years have fostered an impression of instability and political influence that has its effects internally, and is also sensed by the worldwide audience;

- the inertia of government decision making and inter-agency relationships at all levels, be it for a simple matter such as salary scales or for a major initiative such as negotiation and equipage of a new site, makes progress seem painfully slow, and things that ought to be settled within a few weeks or months can often drag on for a year or more.

Given all of the above, it has become difficult for the VOA not to become totally occupied with the day-to-day problems of operating an aging plant, with little freedom or resources for planning for the future in a broadcasting environment that is changing rapidly, and that now needs new technological approaches to properly present the VOA message to its World audience. A few of our specific observations follow.

B. PARTICULAR PROBLEM SITUATIONS NOTED

In our visits to VOA facilities, we were struck by the large amount of manual endeavor and complete lack of automation aids in such operations as: the handling, editing, and distribution of news and commentary material; for the very complex process of scheduling program frequencies and transmitters for the four broadcast periods of each year; and in the transmitter/receiver site operations (at least at the Greenville, North Carolina installation). It is apparent that many have tried over the years to bring automation aids to these operations, but with little or no success. In our interviews, we have spoken with former VOA staffers who said that they had left because they had become frustrated by the slow pace of events and the consistent turndown of their requests and plans for equipment to improve the efficiency of operations such as those mentioned above.

1. COPY PREPARATION AND DISTRIBUTION

Newsroom operations look like a newspaper office of 40 years ago, with only paper copy for proofing and editing. Once copy is ready, it is transmitted by teletype, even though the destination programming or translation office is in the same building. VOA must have one of the larger collections extant of slow, 1930's-vintage teletype equipment (Model 28's), with which it handles an enormous daily message load (as much as 380,000 characters per day) just within the "C" Street building. All transmission is by manual keying, and most copy gets re-keyed several times -- before and after editing, after translation, etc. Delays in message delivery are up to several hours, and the problems of keying errors are ever present. If ever there was a situation that was ripe for computer automation, this is it. Computer data-base systems, with on-line entry and copy editing via CRT terminals and instantaneous copy delivery anywhere needed, are now _de rigueur_ in the newspaper business, even for small-town newspapers. The VOA should quickly follow suit and eliminate the present clumsy, slow, and labor-intensive method of passing material from office to office.

2. FREQUENCY SCHEDULING

We have spent a good deal of time trying to understand the frequency scheduling process, which is a most important aspect of VOA operations. The process starts with program sheets developed by the Office of Programs that list the times of day and destinations for all the intended programming for a future broadcast period eight or more months off. The Frequency Division then works up site, transmitter, antenna, and frequency schedules, using the NTIA/ITS HFMUFES propagation predictions (also for eight or more months ahead), monitor reports on past broadcasts, and any available information on schedules, transmitter assignments, and frequencies that other broadcasters intend to use for the same broadcast period, particularly the BBC and the Deutsche Welle. If the resulting facilities schedule is not possible, given the VOA's signal strength and multi-transmitters per time zone guidelines, program schedule changes may have to be worked out with the Office of Programs.

This is followed by coordination with the BBC and the DW (with possible modifications), ITU submission (six months ahead), and a series of working ITU meetings to resolve difficulties that appear when the proposed schedules of all the World's broadcasters are merged, again resulting in possible changes. Thus, the Frequency Division is constantly concerned with three or more future schedules at any one time. It divides the World into four regions that are relatively independent from the point of view of frequency usage because of their physical separation and/or beam directions. We understand that although scheduling each region is properly a full-time job for two people, and that this was the number (8 total) that was used a few years ago, only two people are presently available for all four regions. The current scheduling process may therefore be hurting.

The process as presently practiced is intensely manual, using the proposed program schedule in combination with a number of voluminous documents (HFMUFES printouts, VOA facilities handbooks, competing schedules (BBC, DW, etc.), monitor reports, operations guidelines on facility retuning times, and so forth. Because all the various factors are so interlocked, and the problem is so multidimensional, seemingly simple changes in a region may be almost as difficult as the original schedule for that region. We gather from some of our discussions with VOA personnel that the difficulties of scheduling are not always appreciated in Programming, especially by new personnel just on board. Some were particularly critical of Engineering in regard to the Polish situation in early 1981, when major programming shifts were needed on a short time scale to meet Administration desires.

We believe that the VOA should make the development of a computer-based scheduling process one of its highest priorities.

By this we do not mean fully automatic scheduling. The problem is so multi-dimensional that probably no one could devise the proper optimization criteria for automatic operation. * What seems practical is a computer-aided data-base system that can automate all the tedious back and forth, combinatorial lookups associated with any particular proposed transmission.

Such a program could, for example, quickly present all the possible site, frequency, transmitter, and antenna combinations for a proposed program, taking into account a set of criteria, the predicted propagation conditions, and all other available information on frequency usage by others at the proposed time. Those selected by the operator would then be automatically added to the facilities-usage data base, and taken into account in presenting possible choices for the next program, etc. If conflicts develop as the schedule nears completion, requiring changes in earlier decisions, the program could check all ramifications of any proposed change and list any problems encountered.

This sort of program, called "computer-aided" as opposed to "automatic", has been highly successful in such applications as air defense (SAGE) and the growing number of design programs for VLSI circuits and mechanical parts and systems, all applications

* Past attempts to devise automatic redistricting programs for political districts have all failed for this reason. Computer-aided programs, however, do work, where humans make decisions interactively with the help of a computer.

in which optimization criteria are almost impossible to quantify and human judgement must be involved.

The ITU has, of course, programs for testing incompatibilities in its composite world schedules. (22) Such a capability would have to be a part of a scheduling program. We have learned that there is work going on in England on computer-based scheduling. We have not heard any details of this work, but it should certainly be looked into as the basis for any VOA development. We might also note that the propagation data base is already available at NTIA/ITS, and could be made available by data link or tape.

Again, we stress the importance of bringing modern technology to the frequency scheduling process. Not only would this improve productivity, it could possibly result in better schedules. It would also expedite the process of schedule adjustments and be invaluable in crisis situations when substantial programming changes are required on short notice.

(22)
"Computer programmes for determination of incompatibilities in the Tentative High Frequency Broadcasting Schedules (RR Article N15/10)," IFRB Circular-letter No. 461, 25 July 1980.

3. STATION AUTOMATION

We have no specific recommendations concerning particular automation equipment or the degree of automation VOA should strive for. It is stating the obvious, however, to note that VOA could save substantially in operating expenses if fewer people were required to operate the equipment for a given level of programming service; also that the use of more modern equipment than VOA has in the bulk of its plant could greatly reduce the time required for changing transmitter frequencies and improve the ability to obtain maximum transmitter utilization in the morning and evening prime time periods. In older, manually operated installations, such as Greenville, North Carolina, transmitter frequency changes within the same band take only 10-20 seconds, but band changes take 15 minutes for 250-kW transmitters, and 30 minutes for the 500-kW units. One or more people are needed during a band change. More modern transmitters, of which VOA has examples at Tinang in the Philippines, can be switched to any of 100 pre-set frequencies within 30 seconds, regardless of band.

Completely automated, unattended HF broadcasting sites are also quite feasible, as illustrated by the Swiss six-transmitter station at Schwartzenburg, controlled remotely from Zurich. We understand that the BBC also has one or more remote, unattended sites in the British Isles. In both of these situations, the sites are not too far away from the home base, and can be reached without undue delay in case of trouble.

A valid concern of VOA Engineering about completely automated sites is the great geographic separation of its sites and the poor accessibility of some by commercial transport, both factors which lead to long travel times. This argument has been raised in connection with proposals that the planned new MF installations in the Caribbean be unmanned. A counter argument that we have heard voiced is that in this particular case, any of the sites could always be reached within a few hours from Washington if VOA were to maintain small jet aircraft for this purpose (or make arrangements for priority, on-call use of other government or private air service aircraft), and that this would be less costly than manning the stations with people competent to fix any and all troubles. (Note that since these are single transmitters operating on single, fixed frequencies, no operator-type personnel are required on-site. Also that a substantial number of AM and FM commercial stations in the U.S. already operate unmanned transmitters, apparently without difficulty.)

The situation in many of VOA's overseas sites, present or potential, are quite different in regard to unmanned operation. Those without access to commercial power must have people to handle fuel for their generators, and the generators are probably not amenable to unattended operation in any case, certainly not for lengthy periods of time. We have also heard concerns about the security of unattended sites, particularly in countries having a lack of political stability. Finally, there are the problems of obtaining and maintaining reliable data links for control purposes. A satellite circuit outage in VOA's present program feeds affects only the ability to broadcast that program, but a similar outage in a remote control circuit could be disastrous. The time-to-reach argument is also valid.

It can be concluded that VOA should push forward into automation of station equipment, both for operational savings, and for faster response times in the constant reconfigurations that take place during any operating day. The degree of automation, however, should depend on careful cost-benefit analyses, and considerations such as those that have been mentioned.

APPENDIX

Documents that were provided to non-VOA contacts prior to interviews as a basis for discussions.

Background Information on the Voice of America - 6/3/1982

VOA Questions (prepared by M.I.T.) - July 1982

BACKGROUND INFORMATION ON THE VOICE OF AMERICA

Prepared for the MIT Research Program on Communications Policy
by John E. Ward, MIT Laboratory for Information and Decision Systems
(Telephone 617 253 3891, Bldg 35-402)

Present Operations

The voice of America operates with the following charter established by the Congress:

> The long-range interests of the United States are served by communicating directly with the peoples of the world by radio. To be effective, the Voice of America (the Broadcasting Service of the United States Information Agency) must win the attention and respect of listeners. These principles will govern Voice of America (VOA) broadcasts:
>
> (1) VOA will serve as a consistently reliable and authoritative source of news. VOA news will be accurate, objective, and comprehensive.
>
> (2) VOA will represent America, not any single segment of American society, and will therefore present a balanced and comprehensive projection of significant American thought and institutions.
>
> (3) VOA will present the policies of the United States clearly and effectively, and will also present responsible discussion and opinion on these policies.

VOA currently broadcasts in 39 languages with a total program output of 138 hours per day. It uses 97 HF (shortwave) transmitters, 67 of which are in overseas sites, and 8 MF (medium frequency, AM broadcast), seven of which are overseas.

The 74 overseas transmitters are grouped in 12 relay sites located as follows:

Poro, Philippines	Tangier, Morocco
Tinang, Philippines	Columbo, Sri Lanka
Kavala, Greece	Bankok, Thailand
Rhodes, Greece	Tangier, Morocco
Munich, Germany	Botswana
Monrovia, Liberia	Wooferton, U.K.
Antigua (Brit. West Indies)	

The five largest of these (Kavala, Tinang, Monrovia, Tangier, and Wooferton) can broadcast on as many as 10 different short- wave frequencies simultaneously, using directional antennas to aim at specific audiences as much as 6000 miles away. The MF transmitters provide more local coverage, but can be directed to specific quadrants.

Delivering Programs to Listeners

Because of the vagaries of HF ionospheric propogation, the VOA simulcasts on three different shortwave bands to make sure of reaching an audience in a given time zone, plus two additional frequencies for each additional time zone to receive the same program. Thus to cover three time zones in the USSR with the same program at the same time, seven transmitters are required, usually spread over several relay stations. These are the rules for an unjammed environment. In the presence of jamming, one or more additional transmitters are scheduled per time zone. (Other aspects of jamming are discussed later.)

The VOA also concentrates most of its programming in the 5:30-8:30 am and 6:00 pm-midnight time blocks (local time) when the intended audience is must likely to be listening. This means that a number of different language programs must be directed to a given time zone simultaneously, each requiring three or more transmitters (as above). These two factors dictate the large number of transmitters required in VOA's worldwide network, and an approximate 1300 transmitter hours per day for 138 hours of programming (assuming that average transmitter utilization is 12 hours per day).

As an indication of the strong coupling between program hours and the number of transmitters, a current VOA estimate is that 31 additional HF transmitters will be needed overseas to increase daily programming by 18 hours (to 156 hours). This is a 42 percent increase in transmitters for a 13 percent increase in programming.

In addition to the above issues, VOA does not at present have complete coverage of all those areas of the world that it would like to reach with a signal of sufficient strength for easy listening. For a number of years, the VOA coverage diagrams have been based on a minimum delivered signal strength of 1 millivolt per meter for unjammed channels, and 2.5 mv/meter (to the extent possible) for jammed channels. While there is a question of whether these are the correct signal levels, however new sites and/or transmitters are clearly needed to cover the following areas, even if the new installations already requested for FY'83 are approved:

Southern South America
Europe
Mexico
North Africa (Mediterranean Coast)
Southeast Africa
South-Central Asia (a radius of 1000 miles around Kashmir)

VOA's current projects, for which funds have been requested but not yet approved, include:

Sri Lanka - Present facilities are three 35-kW transmitters. Plan to install two 250-kW and four 500-kW.

Botswana - Present facilities are one 50-kW MF and one 3-kW HF transmitters. Funds requested to install four 250-kW HF transmitters (already owned, reprogrammed from 1977 Liberia authorization).

Is Present Transmitter Power Sufficient?

A further coverage problem is that VOA has not remained competitive with other nations in HF transmitter power. Half of VOA's overseas HF transmitters are 250 kW; the rest 35-100 kW. Its only 500-kW units (six) are at Greenville, N.C. Other nations currently operate 87 HF transmitters of 500-kW rating, with another 31 under construction. There is a question whether VOA should go to 500 kW on all new transmitters (and gradually upgrade older ones) to maintain competitive signals.

Obtaining and Maintaining Site Agreements

Another interrelated problem is the political one. All present overseas sites are maintained only with the forbearance of the host countries, and some are considered vulnerable at the present time. The Greek government, for example, has not signed the new 15-year agreement for the Kavala and Rhodes sites, worked out with the previous government. The VOA has lost sites in the past. A former site in Okinawa was closed down 10 years ago when the Japanese Government did not renew the agreement, leaving only the Philippine sites to cover the whole of the Asian continent. An anticipated future loss is that the BBC, which operates 10 transmitters at Wooferton for VOA, apparently will exercise "prime use" right on six of these transmitters in 1992, thereby causing VOA to look for other sites in this region within the decade. Negotiations for new sites can be quite difficult and drawn out, and must include considerations of the host country's relations with the target countries. For example, Israel might well agree to a VOA facility for USSR-language broadcasts. For diplomatic reasons, however, the VOA would not wish to use a relay site on Israeli territory for Arabic-language broadcasts to Israel's neighbor countries.

Jamming

After a hiatus of seven years, the USSR resumed jamming of VOA broadcasts to the Soviet Union on August 20, 1980. Current jamming of VOA, RFE/RL, BBC, Deutsche Welle (DW), Kol Israel, and Radio Peking transmissions to Soviet-bloc countries is extensive, using both sky-wave jamming for distant areas and ground-wave jammers for local, metropolitan areas. The effectiveness of ground-wave jamming within the USSR can only be surmised. Sky-wave jamming, however, also affects areas far from the USSR. A March, 1982 survey indicates that roughly the following percentages of all channels in the 7-, 9-, 11-, 15-, and 17-MHz bands are essentially useless in the evening hours 1700-2300 local time in the indicated locations (Ref. 2):

Monitoring Location	% of Channels Useless
Belgrade	52
Helsinki	38
Vienna	51
Nairobi	57
Islamabad	46
Hong Kong	31
Washington	19

(These percentages are averaged from hour-by-hour percentages for each band: excluding Washington, the raw data spread is from 26 to 86 percent useless channels for particular band-hour-site combinations.)

The only real solution to jamming must apparently be a political one, since no feasible technical solutions have emerged (except to go to higher signal strength levels and more simultaneous transmission frequencies in an attempt to break through). Until jamming can be stopped, or some means of combating it devised, the VOA must be content with greatly reduced effectiveness in reaching many of its targets. At the same time, the present deliberate negation of half of the most useful short-wave channels represents a world-wide problem that will no doubt be a major issue at the upcoming International Telecommunications Union short-wave conferences in 1984 and 1986.

Program Feeds from the US

VOA maintains a complete world-wide HF-relay method of distributing its programming, all of which originates in the Washington studios. This includes three U.S. sites with 24 transmitters; the North Carolina site also directly serves South American listeners. Each of the 15 VOA transmitter sites has a separate receiving station located 20-30 miles away, some of these having as many as 20 large rhombic antennas aimed at other sites to receive programming from them. Program quality deteriorates the more relays (receptions and retransmissions) are needed to reach a given transmitter site. Starting in 1978, the VOA began using commercial satellite circuits to some sites, leasing local telephone authority (PTT) landlines to get from the host-country PTT downlink to the VOA transmitter site. Reliability has been a problem, particularly with the leased land lines. VOA would like to install its own receive dishes on-site, but political problems prevent this at present. VOA therefore feels that it must maintain and man its HF relay system as backup for the foreseeable future. Also, some sites are not currently reachable by satellite-PTT links.

Access to the Shortwave Spectrum

VOA uses all nine of the international shortwave bands, which are:

Wavelength (Meters)	Band Limits (MHz)
75	3.9 - 4.0
49	5.95 - 6.2
41	7.1 - 7.3
31	9.5 - 9.775
25	11.7 - 11.975
19	15.1 - 15.450
16	17.7 - 17.9
13	21.0 - 21.75
11	25.6 - 26.1

The actual frequencies used within these bands are coordinated on a quarterly basis with other non-Soviet-bloc countries through the ITU (the best frequencies for particular paths change with the season of the year and with the sun spot cycle). The 26-MHz band is the least used by VOA (and other world broadcasters) because it is seldom in the range of useful ionospheric propagation frequencies; also only a small fraction of the world's shortwave receivers will tune to this band.

The best bands for particular paths also change by the hour on a daily basis, as illustrated by the attached plot (Ref. 1). The VOA therefore predicts the average hourly propogation conditions for each month of the year along some 200 paths between sites (for program feed) and between sites and listener areas. These predictions are used to schedule which transmissions should use which frequencies at which times. The prediction is by computer program (some 620 pages of printout), but the scheduling is largely manual. In order to accomplish the necessary ITU coordination, the predictions must be made seven months ahead, preliminary coordination is started six months ahead, and monthly coordination update continues until the schedule goes into effect.

As more and more of the world's 130 countries enter the HF broadcast arena and/or broadcast in more languages and to new areas, the bands are becoming very crowded. VOA is concerned about future access to the spectrum, particularly if the present rules for frequency coordination (adopted in 1948) are changed at the international shortwave meetings upcoming in 1984 and 1986.

Potential New Technologies

During the past few years, there have been several proposals for use of direct-broadcast satellites (DBS) to augment or supplant present HF ionospheric voice-radio transmissions. The 26-MHz band has been considered in several of these because it is already assigned for international broadcasting, is little used, and appears to be reliable in ionospheric penetration, whereas it is not in surface-to-surface propogation via ionospheric reflection. (VOA is also interested in examining the feasibility of DBS on lower HF bands -- e.g., 21 and 17 MHz -- because of the much greater number of in-place receivers world-wide.) Very large space antennas and high transmitter power are, however, required for HF DBS operation if the goal is to deliver signal levels of one millivolt per meter (or more) for "radio" listening. Much more economical spacecraft could be built if a much higher frequency could be used, but then there would be the problems of finding spectrum space, and getting proper receiving equipment into the hands of world-wide listeners. The latter would also be a problem for 26-MHz DBS, as has been discussed, but UHF or SHF reception would probably also require high-gain antennas, which could create difficulties for would- be listeners, particularly in Soviet-bloc countries.

The question of DBS has arisen in all recent discussions of VOA planning as a potential solution to many of the issues that have been discussed herein -- coverage, overseas sites, power, jamming, spectrum access, and cost per channel hour. However, there are very large technical, cost and political issues to solve before general use can be made of DBS (not to mention the problems of distributing new 26 MHz or higher-frequency receivers to a worldwide audience).

Another technique that might substantially improve delivered signal strengths for the present ground-based VOA network is to use back-scatter measurements to dynamically optimize the elevation launch angles of transmitter antennas, a technique possibly now being used by Radio Moscow (Ref. 3). Tests performed for VOA by Stanford Electronics Laboratories in 1967 on a one-hop path of 1300 km indicated that backscatter echos could be used to pick the better of two launch angles (10 and 20 degrees) with a reliability of about 80%, and with delivered signal strength improvements as high as 12 dB at some times of day (Ref. 4). Implementation of this technique would require modification of present antennas for elevation slewing (or multiple antennas with different fixed elevation angles for each transmission azimuth). It also appears that to obtain the greatest benefit, a method of obtaining frequent data on actual ionospheric layer heights along all paths of interest would be needed. This is because the layer heights affect the round-trip delay time to any particular point on the earth's surface. Unless the layer heights are known fairly accurately, one doesn't know from what ground range the strongest echo is being returned. Top-side ionospheric sounding from satellites is one possibility.

VOA Statistics

VOA employs some 2000 people, about half overseas, with 700 of the latter being foreign nationals. In addition to budgetary restrictions and Administration edicts against filling vacancies on a one-for-one basis, qualified HF personnel are becoming harder and harder to find, both in the U.S. and abroad. The result is that some headquarters staff, including branch chiefs, have had to be transferred overseas to keep sites running, and their posts remain vacant.

The estimated replacement cost of the present VOA network facilities is $1B. The total transmitter output power (as of 1981) is 20.6 megawatts. The annual operating costs of typical overseas sites are:

Munich	$2.7M (small station)
Philippines	$4.1M (medium-size station)

These include salaries and related expenses for foreign national employees, but not VOA U.S. personnel on-site. The cost of power to operate sites is of increasing concern. For example, the budgeted power cost for the Philippines relay station in FY'82 is $2,280,000, 55.5% of the operating budget.

The current annual operating budget of the VOA as a whole is $108M (FY 1982). The fiscal 1983 budget request is $117M. In addition, VOA has requested $118M in FY'83 for the new transmitter construction in Sri Lanka and Botswana.

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3. "Why Radio Moscow is WINNING the dB WAR," Stanley Leinwall (Director of Eng., RFE/RL), Radio-Electronics Magazine, December 1981, pp 55-57.

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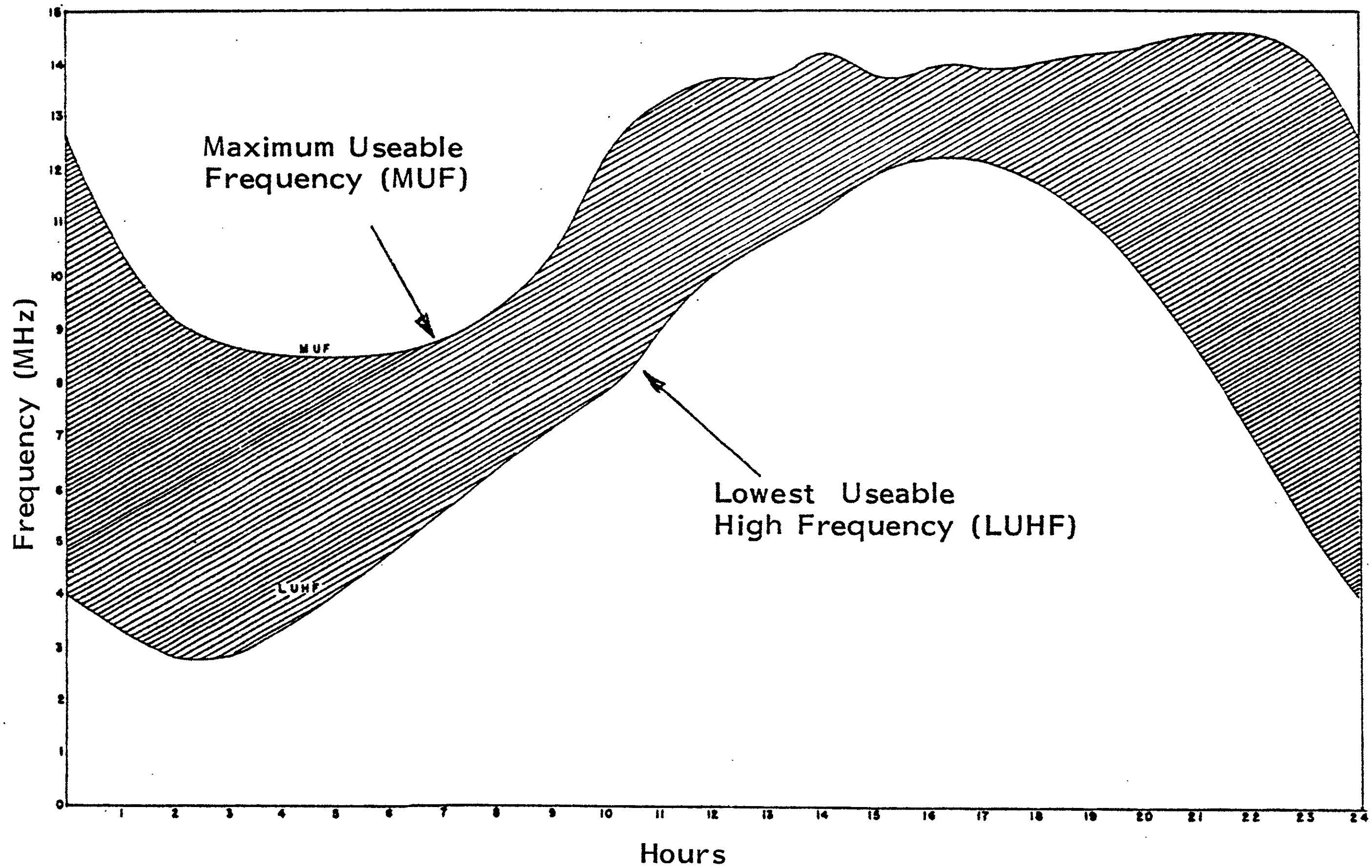

Typical Variation in Useable Shortwave Frequencies over a 24-hour Day

(From Menzel, Reference 1)

In your answers to questions about transmission facilities and capabilities, what are you assuming to be VOA's priorities of purpose?

In ways that affect transmission, what should be VOA's relationship to other HF broadcasters? Are there potential economies of scale in joint facilities?

In your comments about transmission, what are your assumptions about VOA's balance in broadcasting to allies, friends, and foes?

To what extent is relay station planning (upgrades, new sites) affected by uncertainties in future language priorities?

To what extent should VOA conduct regular planning exercises to develop means for quick response to crisis situations, such as the Administration directive in late-1980 to greatly increase daily programming to Poland?

TRENDS IN INTERNATIONAL BROADCASTING.

What is the future of international broadcasting in general? What is the future of high-frequency (shortwave) transmission versus other methods?

Is HF on the increase, decrease, or constant in its importance? In what regions are these trends to be found?

How will the use of HF be affected by levels of RF interference?

How will it be affected by levels of competition for HF spectrum?

Will shifts in audience interest affect HF importance?

What is the payback for U.S. investment in HF broadcasting?

How will the terms of spectrum access needed for international broadcasting change in the future? Will access be different for VOA than for others; or different for some nations or regions than others?

In 1984 and 1986 there will be ITU broadcast conferences. What are the problems likely to be brought up? What will the U.S. have to face? What should the U.S. position be and how will this affect VOA's future plans? What should be the U.S. fallback positions and plans for HF broadcasting?

How does the quarterly frequency bargaining with our friends work out in practice?

Do you anticipate changes in the bargaining process as a result of the upcoming HF conferences?

Can data processing and communications innovations improve the bargaining process?

Do you foresee and changes or improvements in the present system by which host countries obtain operating frequencies for VOA? Are any improvements needed?

How do you feel about the use of MF (AM) or even FM (VHF) frequencies for international broadcasting?

ALTERNATIVES TO HF INTERNATIONAL BROADCASTING?

Direct broadcast satellites (DBS): are they feasible technically? politically? Would they be cost-effective? In your view, what frequencies and technologies should be considered?

Would it be reasonable to lease time on other HF transmitters? What arrangements would make this secure and dependable?

Could the common-carrier concept be applied to international broadcasting whereby equal access would be available on neutral transmitters for all nations? Who would enforce this or regulate charges? Could this concept be applied to a subset of nations willing to cooperate in international broadcasting? (Questions pertain to both ground and DBS transmitters.)

Should the VOA investigate leasing audio channels on CATV systems overseas? Is it likely that such systems would have a significant penetration in developed regions within the decade?

Are there any other techniques for delivering VOA's message that may be effectuated in the next decade or two?

SITES AND EQUIPMENT.

What is the feasibility of high-frequency or medium-wave transmitters at sea?

Are there remote islands and/or desert regions that should be considered as transmitter sites?

What are the economics of many small transmitter sites versus fewer, but larger stations?

What is the feasibility of replacing some or all overseas sites by stateside transmissions, making use of higher power, higher antenna gains, and possibly sophisticated techniques such as backscatter sounding?

Are there any new high-frequency transmission techniques?

What are the possibilities for achieving greater flexibility in the use of transmitters? How can they be rapidly redirected? What affect does that have on programming times and patterns? What are the possibilities for centralized remote control?

JAMMING.

What are the political possibilities of stopping jamming?

Are there any technical solutions?

What are the trends in jamming?

What is the probability that other than Communist-bloc or belligerent nations will start jamming?

Is an increase in transmitter power the most cost-effective means at VOA's command to combat jamming?

Are there advantages of certain transmitter locations over others in regard to relative immunity to jamming within Soviet-bloc areas?

Are there incentives of a economic or technical nature that could lead the Soviets to reduce or eliminate jamming?

Signal delivery standards:

Number of frequencies per time zone when there is no jamming? When there is jamming?

The present VOA goals for minimum delivered signal strengths are 1 millivolt per meter with no jamming and 2.5 mv/m when there is jamming. Are these correct standards? Too large? Too small?

Transmitter power:

Is the present VOA standard of 250 kw sufficient? If not, what power level should be used (500kw; more)?

Present transmitters have efficiencies of about 50 percent. Are more efficient designs possible?

Antenna technology

Should more directive antennas be used to increase effective radiated power (ERP) to counter jamming or other interference in critical, small listener locations?

Does the use of backscatter sounding to dynamically optimize antenna elevation angle as the ionosphere changes represent a feasible and cost-effective way of improving delivered signal strengths?

Most VOA antennas have a single, fixed elevation angle at any given frequency; a few curtains at Kavala have two angles selectable by switching. What elevation slewing capability is needed for optimization of delivered signals by backscatter sounding? How difficult is this to implement? What are the cost tradeoffs versus higher transmitter power?

Backscatter techniques may require frequent, fairly precise data on ionospheric layer heights along the transmission path in order to know at what ground range the signal is being optimized. How can such data be obtained? Top-side sounding from satellites?

Program feeds to relay stations:

Commercial satellite circuits are now providing improved signal quality feeds to some overseas relay stations via PTT local lines. Can on-station receive-only dishes be negotiated to avoid reliance on local PTT circuits connecting PTT downlink facilities with VOA relay stations?

System engineering:

In the total VOA communications system, what interactions are there between incoming and outgoing communications? Between information processing and communications?

What improvements are possible in signal prediction? To what extent does monitoring data help? Should the present level of monitoring activity be increased? Are automatic, unmanned monitoring devices feasible?

Is the present ITU method of calculating interferences between world broadcasters adequate? What improvements could be made?

What R&D capabilities does VOA need for the future?

Automation:

To what degree can new transmitter equipment and stations be automated to reduce operating costs and overseas manpower requirements?