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ABSTRACT

If the Corporation for Public Broadcasting (CPB) is eventually to serve all citizens with public radio and television, technological and regulatory innovation will be required. Service to rural America and service to specific groups within urban areas cannot be accomplished within the limits of existing technology and existing spectrum allocation policy. Improved service can come from several areas. Cable, video cassettes, and discs can be new spectrums for new audiences. Cable can recreate the entire spectrum as many times as there are cables, but now it is too expensive for complete nation-wide coverage. Video cassettes and discs are spectrums of a sort which can relieve problems of scheduling and transmission in the airways. Yet they, and the equipment needed with them are expensive, bulky, and not widely used. Communication satellites have three potential uses toward expanding the broadcasting spectrum. In order of increasing complexity and cost, these are the provision of: (1) network service to television stations, (2) signals to unattended "ministations" located in remote areas of the country, and (3) signals to individual home receivers. The spectrum is the critical element to the existence and expansion of public service. The current problems of the UHF band and the FM spectrum will be solved through the development and integration of new satellites, an increased efficiency in any present spectrum usage, and a commitment to today's stations. (Author/DAG)

"THE OPTICAL NATION"

Statement by Philip A. Rubin before the
Subcommittee on Communications
House of Representatives, August 4, 1977

Statement by
Philip A. Rubin
Director, Engineering Research
Corporation for Public Broadcasting
Before the
Subcommittee on Communications
Interstate and Foreign Commerce Committee
United States House of Representatives

Hearings On
Broadcasting and New Technologies
August 4, 1977

The Corporation for Public Broadcasting is charged by the Congress with effectively making non-commercial educational radio and television service available to all citizens of the United States. In carrying out that mandate we have become increasingly aware that the eventual goal of serving all citizens with public radio and television will require technological and regulatory innovation. This is especially true if we are to serve the rural population of this country which is difficult or impossible to reach using conventional broadcasting techniques, and which heretofore has been deprived of the educational and cultural resources commonly available in the larger cities. We are also aware that the programming needs of our larger cities are not as homogeneous as once thought, and that there exists a need to provide programming to disparate, identifiable ethnic and social groups within a city Both of these tasks, service to rural America and service to specific groups within urban areas, cannot be accomplished within the limits of existing technology and existing spectrum allocation policy. Let me explore the frontier of broadcasting technology and what the outlook is for providing additional service to the public.

Creating Spectrum

Unlike energy, CPB suggests that the spectrum is a resource which can be created, especially for what has become known as television. For all too long, the small segment of air waves dedicated to delivering information (television and radio) to the home has been reserved for a privileged few, the commercial and public broadcasters. For the most part, their duties have been carried out responsibly within the economics of today's marketplace. However, the ever increasing role and leverage which television and radio have on our lives has demanded more from the air waves than they can deliver. Now, with the potential of cable and video cassettes and discs, new spectrums can be created, new users can emerge, and the citizens of this nation will be the [illegible] beneficiaries.

Cable

Although coaxial cable has been with us for over 40 years, it was not until the 1950s that its potential role in television surfaced. It took another 20 years for engineers to realize that cable represents more than a medium of retransmission. In fact, cable can recreate the entire relevant frequency spectrum The spectrum which we have learned to value and harbor, can be fashioned, encapsulated and reused as many times as we wish, by using more and more cables. For the broadcast industry with its insatiable appetite for spectrum, cable and its eventual replacement, fiber optics, provide a viable solution. This solution, however, may still be 10 to 20 years away. The economists tell us that such concepts as the "wired nation" or the "optical nation" are prohibitively expensive using today's raw materials, manufacturing and installation costs As the use of LSI technology and advanced microminiaturization moves into cable and optical fiber equipment, costs will be reduced. The actual wiring-up process still remains a formidable obstacle, as does the enormous capital investment required for such a program. As such, the implementation of these technologies (cable and optical fiber) likely awaits the economies of scale to be achieved through a massive, possibly government financed, national program dedicated to providing a multitude of communication services to the home. In other words, we must look elsewhere for additional spectrum for the immediate future.

Discs & Cassettes

One such avenue is the video cassette and the video disc Although these new technologies have already made some impact in the educational and institutional field, the mass market acceptance of these products is yet to be tested. Here again, it is possible to look upon these devices as creating spectrum, but in a more limited fashion. Each time a user employs cassettes or discs (video or audio) in effect the spectrum has been relieved of problems of program scheduling and transmission, these problems themselves having been a by-product of the inadequate spectrum available in the first place.

Each medium, cassettes (tape) and discs (records) has its own unique advantages and drawbacks Cassettes can record and be edited by the maker, as well as be reused up to a point. On the negative side, cassettes can be expensive and are subject to natural magnetic forces which can impair their quality, and furthermore are complicated mechanical devices by virtue of their construction In addition, their very facility of being a recording vehicle has raised complicated questions of copyright which may take years to sort out. Discs on the other hand are largely indestructible, have the potential of very low cost in large numbers, and in certain versions can act as a virtual storehouse of information, standing ready to provide selected information at the press of a button. The disc's drawbacks are the expense to make a single or limited number of copies, and the inability to make one's own recording. Also, the disc can be stored easily requiring no more room than an audio record, while tapes do take up significant space and must be stored in a proper environment. While discs can be stamped out in enormous quantities, tapes do not lend themselves to easy reproduction, and the cost of copies does not appreciably reduce as more copies are made. However, both technologies offer interesting attractions which must be measured against a user's needs. We should not dismiss either at this time. Cassettes are already in use in many areas, and video discs although not presently available except on an experimental basis, are expected to reach the mass consumer market later this year. The widespread acceptance of either medium will open the floodgates of television to producers and artists, and take some pressure off the spectrum. However, television's ability to be the eyes of the nation requires a "liveness" unavailable on any recording device. News and public affairs, sports, and the transmission of live entertainment events are still unique to television. This coupled with the economics of movies and other theatrical events point to the use of such programs on television first, and then on recorded formats sold to the public.

Thus, neither the advent of cassettes nor of tapes can be expected to materially relieve the pressure for more television avenues to the public in the immediate future. But there are other technologies which do impact on this arena.

Communications Satellites

As the subcommittee is aware, distribution of programming to public radio and television stations will shortly be accomplished by multiple-channel satellite transmission rather than the current common-carrier facilities utilizing terrestrial microwave. This function is by no means the only way in which satellites can be used in [illegible]cast service. In order of ascending complexity and cost, the potential uses of satellites in broadcasting include:

1. Providing network service to television stations—the function described above.
2. Providing signals to unattended "mini-stations" located in remote areas of the country.
3. Providing signals to individual home receivers, a function known as "direct-satellite-to-home" broadcasting.

Item 1, above, is a soon to be accomplished fact, and will allow public stations access to a greater diversity of program selection by virtue of the multi-channel capabilities of the satellite.

Item 2, above, holds the promise of meeting the needs of rural viewers and listeners, in a feasible and economical fashion. At present, many rural areas are served by radio and television translators, unattended devices usually located on high terrain, which receive the signals of a distant radio or television station, and re-broadcast the signals on a different channel using low power transmission, ranging from one watt to 100 watts. Translators have been valuable in extending television and radio coverage into remote areas However, they have a singular and obvious inherent disadvantage, because, for proper operation, they must have a reliable signal from a "parent" television station. In many rural areas, signals from such "parent" stations, particularly public stations, are not available because the closest station may be several hundred miles distant. Using a new generation of shuttle launched satellites (e.g., Syncom IV), and operating in non-common carrier-bands (e.g., 2500 MHz), low-cost earth terminals can deliver high-quality program related signals to unattended "mini-powered" television stations for rebroadcast in rural areas. This type of satellite is well within today's technology and with the first Space Shuttle flight will become an economic reality. Eventually, such service could also be used to augment the primary networking function of the system being constructed today, however, early satellite channel capacities are somewhat limited due to the multi-purpose nature of the spacecraft.

This delivery capability coupled with changes in the allowable power of "mini" stations (modified translators) could make rural coverage an imminent reality. The present arbitrary power limitations of 1 watt-VHF and FM translators east of the Mississippi and 10 watts west of the Mississippi, and the equally outdated limitations on UHF transmitters should be eliminated and replaced with a requirement that maximum power be determined on the basis of the size of the rural area to be served, constrained only by the avoidance of objectionable interference to nearby stations.

The facility previously described does not constitute a "translator" within the commonly accepted definition of that term. Instead it is a wedding of a satellite earth terminal and certain components of a conventional translator. This constitutes the most feasible and most economical means of providing service to rural areas, where the low population density does not warrant the installation of a conventional wide-area coverage station. The principle is readily adaptable to both radio and television, and CPB studies are currently under way investigating the technical, economic and regulatory factors associated with implementation of this system of extending public broadcasting service to rural areas.

The third item—direct satellite-to-home broadcasting—is within the realm of technical possibility today, and is considered as one of the long term solutions to delivering adequate public broadcasting service to isolated rural areas which cannot be economically served, at present, either by conventional broadcast stations or by the previously described satellite earth station translator combination. However, despite its demonstrated technological feasibility, satellite-to-home broadcasting poses some formidable economic and spectrum utilization problems. The economic problem is twofold. The first economic problem concerns the cost of satellites which have sufficient transmitter power to place relatively strong signals on the earth's surface so that reception with a home antenna of reasonable size is possible. The second economic problem involves the cost of the receiving antenna and converter necessary to deliver the satellite signal to the home television receiver. It is anticipated that both problems will yield to technological progress, and that with continued refinement of satellite technology, the costs of both the satellite and the receiving apparatus will become more affordable. The spectrum utilization problem appears more serious because of the burgeoning use of satellites for such commercial purposes as data transmission and telephone communications. It is urged that the regulators of the spectrum recognize that, for many commercial users, satellite transmission of information constitutes merely a more economical alternative to the use of terrestial radio systems and wireline communications, and that these less spectrum-intensive systems will meet the needs of commercial users, albeit at greater expense. By comparison, use of terrestial radio or television systems or wireline munications is not a feasible means of delivering public broadcasting programming to areas of low population density. This is not to say that commercial users should be precluded from use of that portion of the spectrum suitable for satellite service. Rather, it is a plea that considered forethought be given to equitable allocation of this portion of the spectrum, so that when direct satellite-to-home transmission of public broadcasting programming becomes an economically viable proposition, the public broadcasting community will not find that area of the spectrum so saturated by other users that implementation of this public service is impossible or unduly limited.

Technological Advances

Engineers have long recognized that certain of the transmission methods used by broadcasters are inherently inefficient to the extent that they utilize excess spectrum space. Fortunately, the crisis of spectrum shortage has arrived accompanied by advances in technology which hold the promise of increasing the amount of information which can be "squeezed" into a given unit of spectrum. As with most engineering matters, certain trade-offs exist when spectrum conservation is attempted, and it appears that providing additional programming by making more efficient use of the spectrum will exact costs in the form of more complex, and hence more expensive, receiving systems. In assessing the desirability of methods of making additional programming available, it is important to recognize that the traditional solution of allocating more spectrum has nearly reached the end of its utility, and is not a viable solution for the long term. The alternative is not between allocating more spectrum or making more efficient use of what spectrum we have. Instead, the stark reality is the choice between making more efficient use of what spectrum we have, or doing without additional communications service to a growing population which exhibits an almost addictive dependency on the benefits which such service confers.

The area which appears most in need of technological innovation to improve spectrum utilization is broadcast television. The television signal as presently constituted is wasteful of spectrum space because much of the information transmitted is highly redundant in its technical content. Theoretical research and some prototype systems have shown that elimination of the redundant information and utilization of storage circuitry in television receivers can reduce tele- signal spectrum occupancy by up to ten times. One system developed by the General Electric Company, and denominated "Sampledot" takes advantage of certain psychophysical characteristics of the human eye-brain complex, and eliminates apparent "flicker" in a narrow bandwidth television picture by "building" a picture out of a series of random dots, rather than using the linear scan system of conventional television systems. A Westinghouse system called "Two in One" television is capable of transmitting two separate color programs on a single television channel. In a practical implementation of this system, a single television station operating on, for example, Channel 5, would transmit two programs simultaneously, using the same transmitting equipment now required for the transmission of a single program. The viewer, equipped with a special receiver capable of "unmixing" the two programs, would select the desired program by tuning his special receiver to "Channel 5A" or "Channel 5B."

These systems both offer savings in spectrum occupancy and in the capital cost of the transmission apparatus. The price paid for the resulting additional program capability is an increase in the complexity and cost of the television system which has long been the "weak link" with respect to efficiency in spectrum utilization. Based on CPB's assessment of the current state of the art, these or similar spectrum conserving systems could be implemented for consumer use within the next ten years.

Further along the technological horizon lies the development of the transmission broadcast television signals by digital, rather than the current analog means. Given inexpensive digital storage circuitry, of the type presently in use for computer data storage, the need to transmit redundant information would be eliminated. Information presently transmitted redundantly would be transmitted only once and stored in the television receiver and displayed for as long as necessary. "New" information would be transmitted only when there was a change in the television picture. Stated otherwise, the television system, instead of transmitting many duplicate "still pictures" would transmit only "changes" in picture content. At present, the digital circuitry to accomplish this function is bulky and expensive. However, miniaturization and cost reduction in electronic circuitry has been the rule over the past decade, and engineers today utilize hand-held $100.00 digital computers, which 10 years ago would have cost close to $1,000,000 and would have occupied a good portion of this hearing room. Recently, many of the analog devices in television stations have been replaced by more reliable and less costly digital apparatus, and the expansion of digital techniques into the home television receiver, and the resultant reduction in spectrum occupancy requirements, seems an inevitable and highly desirable natural consequence of continued research and development in this field. The long term need for additional programming capability within the confines of the limited available spectrum is intimately tied to the implementation of digital transmission techniques, and progress in this area will be closely followed by CPB, other representatives of the public broadcasting community, and the television industry as a whole.

Radio, too, shares some of the spectrum inefficiency characteristics of television, but not nearly to the same degree. However, improvements can and should be made, particularly in FM broadcasting. The FM broadcast band in the United States has reached the point of saturation in densely populated areas, and absent technical and regulatory changes, no new stations can be established. With respect to the small and crowded non-commercial portion of the FM band, CPB has advanced proposals for FCC rule changes that will provide some small number of new additional stations. However, to realize significantly greater numbers of non-commercial FM stations, major restructuring of FCC technical standards and implementation of innovative technology will be required. At present, each FM broadcast station occupies ten times more spectrum space than its AM (standard broadcast) station counterpart. By utilizing this additional spectrum, FM stations are able to offer better performance with respect to a parameter known as "signal to noise ratio." This improvement translates into a received sound that is relatively free of common radio impairments collectively grouped under the heading of "noise." Preliminary research by CPB indicates that a reduction in the amount of spectrum occupied by each FM station may be possible with only a slight reduction in signal to noise ratio performance. Furthermore, this slight performance deterioration could be compensated for by incorporation of available noise reduction equipment such as that marketed by the Dolby Company and the dBx Company, to name just two. The effect of the reduction in spectrum occupancy would be to provide "room" for additional stations which could be added by a technique we refer to as "channel interleaving"—or placing new stations in the spectrum "slots" which result when the spectrum occupancy of existing stations is reduced. When research is complete, CPB plans to petition the FCC for regulatory implementation of the "channel interleaving" proposal. To date, this plan appears to be the only technically and economically feasible means of relieving the intolerable shortage of spectrum for public radio.

Conclusion

To broadcasters, public and commercial alike, the spectrum is that crucial element on which they are dependent for the existence and expansion of their ability to provide public service. Both broadcasters and the regulators must keep paramount in their planning, the concept that spectrum is a resource which must be utilized to the limit of its efficiency. Even with cable, optical fibers and video discs on the horizon, the existing spectrum can and must be made to perform to its peak. Unless we are prepared to foreclose future expansion of service to the public, the force of modern technology must be brought to bear on the critical elements affecting broadcasting and its future. The development and integration of new satellites, the "optical" nation, the video disc, and increased efficiency in our present usage of the spectrum, as well as a firm commitment to today's stations are the areas most in need of attention. For the immediate future, the problems of the UHF band and the FM spectrum have reached crisis proportions. Measures must be taken as outlined here to assure orderly growth and expansion of these services as well as to prepare all broadcasters for the coming revolution in communications.

Philip A. Rubin, Director of Engineering Research and Development for the Corporation for Public Broadcasting since 1970 when the office was created, is responsible for technical research in satellites, cable television, video cassettes and discs, UHF and VHF broadcasting, AM, FM and SCA radio broadcasting, video and audio technology, and the applications of computers to public broadcasting.

In 1965 he was selected as the first Expert in Satellite Communications by the United Nations and named Program Manager of the Centre for Research and Training in Satellite Communications in India.

Mr. Rubin came to public broadcasting from the Space Division of North American Rockwell, and prior to that he worked on communication satellite design for Hughes Aircraft Company, starting with Syncom, Early Bird, and the early ATS satellites. Prior to that he worked for the ITT Research Laboratories on the Relay and Courier satellite programs, and put together the first earth station licensed by the FCC for earth space communications.

He received a B.S. in Physics and Electronics from the University of the City of New York. He is the recipient of the first Harvey J. Aderhold Memorial Award for significant achievement in Educational Telecommunications. He is a member of the Board of Governors of the Institute of Electrical and Electronic Engineers, Broadcast, Cable and Consumer Electronics Society; past chairman of the IEEE Broadcast Group in Washington; and present editor of the IEEE [illegible]sactions on Broadcasting.

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