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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Digital Audio Radio Service Satellite Systems Application Acceptable for Filing, Report No. DS-1244	)))))	Satellite CD Radio, Inc. File Nos.: 49/50-DSS-P/LA-90 50/59-DSS-AMEND-90 44/45-DSS-AMEND-92

Comments of International Radio Satellite Corporation
(RADIOSAT International

1. The International Radio Satellite Corporation (RADIOSAT International) is planning a global satellite system that would offer common-carriage-like service to international short-wave broadcasters worldwide, broadcasting their programs via satellite directly into listeners' radios. The service would not depend on complementary, terrestrial transmission, but would have transmission margins adequate to deliver a high-quality signal to radios in buildings, overcoming foliage and building losses. The system and service were described in Reference 1 (attached).

A worldwide satellite broadcasting system of the kind planned by RADIOSAT International depends upon reciprocity of carriage and transmission. That is, if the service is common-carriage-like, all prospective users must have equitable access to the system and must have assurances that their broadcasts will be receivable in the countries intended. RADIOSAT International has expressions of interest in such a service from the BBC, Deutsche Welle, Radio France International, Radio National of Spain, Radio

Nederland Worldwide, the Armed Forces Radio and Television Service, Radio Free Europe/Radio Liberty, Turkey Radio and Television, and the VOA. All of these international, short-wave broadcasters are planning their transitions from short-wave to satellite broadcasting. Thus, it is in the United States' national interest to allocate radio frequencies to receive such broadcasts from other countries; otherwise, the VOA would likely not be allowed to use such satellite capacity for its broadcasts to those countries.

2. Federal Communications Commission Public Notice 30121, Report No. DS-1244, deals with "domestic digital audio radio service satellite systems (p.2, top of page)" but does not recognize international systems. To the extent broadcasting into the United States by satellite represents a "domestic" service, RADIOSAT International recommends that some portion of the frequency band 2310-2360 MHz be allocated to accommodate that service. If "domestic" service means program materials originated within the U.S. as well as broadcast into it by satellite, RADIOSAT International would take exception to the Commission's proceedings in this matter unless they include resolving the issue of "international" vs. "domestic" service, because the national interest is affected and such resolution is needed to satisfy it.

3. Corollary to this Matter, the Commission released a Notice of Proposed Rule-Making, GEN Docket No. 90-357, on November 6, 1992. The NPRM deals with amendment of the Commissions's rules with regard to establishment and regulation of new digital audio radio services, both satellite and terrestrial. Comment date for the NPRM is January 29, 1993, two and a half months later than the comment date of November 13, 1992 for the Matter currently under discussion. Since the Commission is proposing to

make specific technical and regulatory proposals through the NPRM under which new DARS are to be established, providing a frequency allocation and license to one specific applicant prior to the making of rules for such provision seems to us a defective procedure. RADIOSAT International objects to this placing of cart before horse, and recommends strongly that the Commission complete the NPRM procedures prior to granting any such frequency allocation or license.

4. Satellite CD Radio proposes allocation of the entire frequency band of 2310-2360 MHz available for BSS(sound) to a mobile, point-to-multipoint satellite service (MPSS) and offers a frequency plan that will accommodate it with room for three, two-satellite competitors. The service is based on a single up-link station providing programming and control signals to the satellite. The plan appears to have no provision for systems in which program up-link signals emanate from many points, as would be needed in the case of international broadcasting. Applying the SCDR frequency plan to the entire available spectrum would preclude entry to such systems now or in the future. As SCDR does not appear to need more than 16 MHz out of the entire 50 MHz band, approval of their frequency plan for the services throughout the band is not reasonable. We do not believe the FCC intends to preclude entry of other kinds of BSS(sound) services into the available band, now or later.

5. Report No. DS-1244 says (top of p.2), "Interested parties wishing to file applications for U.S. domestic (underlining ours) digital audio radio service satellite systems to operate in the downlink frequency band of 2310-2360MHz to be considered concurrently with CD Radio's (underling ours) may do so on or before December 15, 1992." RADIOSAT International interprets this to mean

that subsequent filings may be considered after "CD Radio's" has been dealt with. Since Satellite CD Radio appears to need about 16 MHz of the available band, based on its frequency plan and assertion that that leaves room for three competitors, it would seem reasonable to allocate it the spectrum it needs and reserve the remainder for later filing. RADIOSAT International's system plan requires 20MHz maximum, for which these Comments represent notice to the Commission of intent to file later: properly, after completion of the NPRM procedures that should precede action on the SCDR filing.

6. Although its application claims service to "subscriber fixed or mobile receivers", SCDR's major thrust is to car radio service. In that regard their application concedes their inability to penetrate buildings without complementary, terrestrial assistance: a problem they would address later, after their frequency allocation and licenses are granted. By contrast, RADIOSAT International's space-based, direct to-the-radio system is planned to provide power margins adequate to penetrate foliage and buildings, based on results of the Jet Propulsion Laboratory's studies [2]. Service to fixed and portable listeners' radios in buildings is RADIOSAT International's principal objective, although we might also be able to provide mobile services. That is quite different from service primarily to mobile vehicles (operating primarily in the clear) with complementary, terrestrial assistance required. This is yet another reason not to allocate the entire band to SCDR-like systems. Technical standards for propagation margins as functions of the services to be provided have not yet been established. Because such different services have different needs it would be imprudent and exclusionary for the Commission to allocate the entire 50MHz to one type of service only.

7. SCDR asserts that it will provide CD-quality audio (pp. 5,18 of its amended filing) at 128kb/s.(pp. 18, 19). Coding will be either by Dolly AC-2 or MUSICAM algorithm (pp. 35, 50). In a related working paper (CCIR Fact Sheet, WP 10-115-USA-1) SCDR cites a CITEL conference reference (3) to support their claim of CD stereo quality at 128kb/s. The reference paper, however, states that a rate of 192kb/s is required for CD-stereo quality audio; 128kb/s, or 64kb/s per channel, gives only "high-quality" stereo. "High-quality" is not defined, but the reference states that 128kb/s per channel is required for "near-transparent" coding, closest to CD-quality and still at a total of 256kb/s. Moreover, the reference paper discusses compression based on the ASPEC algorithm (Audio Spectro-Perceptual Entropy Coding), not on either Dolby AC-2 or MUSICAM. Although all three use the principle of psycho-acoustic masking, they are different one from another. Thus, it would appear that the technology claimed for compressed, baseband audio coding is not yet available to provide the 30 CD-stereo music channels claimed.

8. A system embodying separate up-links for broadcasters from different countries must also cater to each broadcaster's need to reach a specific language group. The United States contains many such groups in its population, and their geographic distributions are different. Multiple spot beams are necessary to provide appropriate down-links for each broadcaster's language group while controlling the power requirements and costs of the system satellites. This requirement leads to a frequency plan different from that proposed by SCDR: one more reason not to accept the SCDR frequency plan for the entire 50 mHz band.

9. SCDR's application identifies the mobile radio audience as its market, to which it will provide only

music programs by subscription. RADIOSTAT International has identified the international broadcasters as its principal market, to which it will provide carriage for their broadcasts of news, comment, analysis, drama and music to their target language-group audiences. These are very different, almost independent segments of a market some of whose components may well not have been defined yet. Frequency allocations and licenses for the diverse broadcasting services that will satisfy these market segments must be handled very carefully, distinguishing between their characteristics to ensure proper allocations of appropriate portions of the available frequency band to their different requirements.

10. Finally, the SCDR application emphasizes the subscription nature of its service. RADIOSAT International's planned, common-carriage-like service envisions fees for carriage paid by the international broadcasters. While this is not a technical point, it is an important commercial consideration: any allocation and license for a BSS(sound) service at this very early stage in rule-making for DARS must allow for different kinds of services in the available band, commercially as well as technically.

Respectfully submitted,

Richard B. Marsten

Dr. Richard B. Marsten
Executive Vice President and
Chief Operating Officer
RADIOSAT International

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2. Direct Broadcast Satellite Radio, Systems Tradeoff Study, Final Report; Golshan, Nasser. Jet Propulsion Laboratory, California Institute of Technology; March 1992.

3. Sum-Difference Stereo Transform Coding; Johnston, J.D., and A.J. Ferreira, AT&T Bell Laboratories. 1992 International Conference on Acoustics, Speech, and Signal Processing, San Francisco, CA; March 23-26, 1992.

A GLOBAL SATELLITE SYSTEM for INTERNATIONAL RADIO BROADCASTING

RICHARD B. MARSTEN
International Radio Satellite Corporation
(RADIOSAT International)

SUMMARY

RADIOSAT International, incorporated in Delaware in 1989, is planning a global satellite communications system intended initially to carry the radio broadcasts of the international short-wave broadcasters. The initial system will consist of three satellites in geostationary orbit, each having a minimum capacity of 200 monophonic voice and ~~14~~ 20 stereo-music program channels, to provide worldwide coverage to the international broadcasters. The proposed downlink operating band is the 1.429-1.525 GHz portion of L-band, requiring a maximum of 12-16 MHz. Consistent with current short-wave practice, down-link broadcasts will be direct to listeners' radios without the necessity of complementary terrestrial assists. First launch is planned for the last quarter of 1995, with operations commencing in the first quarter of 1996. Planning for mass production and distribution of low-cost radio receivers compatible with the satellite system has begun in preparation for addressing a worldwide replacement market of over 500 million radios. Radio manufacturers will have opportunities to work with RADIOSAT International in demonstration experiments preceding the first launch that will enable them to prove out their designs and gain early visibility and customer acceptance.

The system is based on a modified version of the Eureka-147 signal-processing scheme. Baseband compression and coding schemes have not yet been selected. Several are under consideration, including MASCAM/MUSICAM. CD-stereo quality transmissions have been considered but are not appropriate for the program material of the international broadcasters.

Initial sizing of each satellite was based on 200 CD-stereo quality channels and margins for foliage and building losses to ensure direct-to-listener reception. Propagation studies by NASA and the University of Texas at Austin have shown the margins initially assumed to be excessive. Using their results the satellite antenna apertures could be reduced from 50m diameter to between 14 and 20, increasing the coverage area of each of the 50 steerable spot beams per satellite. The associated spacecraft power supplies are well within the state of the art at L-band, but at the expanded coverage levels possible at L-band could exceed the state of the art at S-band.

International broadcasters would own and operate their own up-link earth stations to gain direct access to the common-carrier-like service of the RADIOSAT International system. Onboard processing of incoming signals, based on the processor technology to be demonstrated in NASA's Advanced Communications Technology satellite in 1993, would work with the RADIOSAT International Network Operations and Control Center to ensure proper assignment of programs to beams and appropriate beam switching and steering. Traffic handling requirements will be developed together with the broadcasters to ensure that the satellite system will meet their needs.

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I. SUMMARY

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II. INTRODUCTION

Today's international radio broadcasters assist their governments in conducting public diplomacy by broadcasting programs of news, comment, public information, and music to audiences that may be hundreds or thousands of miles away. They do this with the best reliability, quality, and audience focus that the technology available to them allows. That includes recognizing that many, or even most, of their listeners cannot afford large expenditures for their radios and must use radios that are easily operated, small, and can be listened to in the privacy of their homes.

Only two technologies can be applied to broadcasting over great distances: short-wave and satellite. Short-wave broadcasting has been used for over fifty years. For most of that time it was the only technology available. It has matured to a stage in which many international broadcasters use several, powerful transmitters simultaneously on different frequencies to ensure that their broadcasts get through to the intended listeners. Even the use of such costly transmitter-antenna arrays and remote repeaters can often not improve signal reception enough because of the vagaries of the ionosphere and because of mutual interference among signals from numbers of countries using powerful transmitting plants arriving in the listening areas simultaneously. The resulting poor reliability and quality of short-wave broadcasting is causing a loss of audience population to other, better-quality radio media; for example, FM.

With advances in satellite broadcasting ~~and communications~~ technology since its first demonstration in NASA's ATS-6 program in 1974, it is now clear that this technology, properly implemented, could go far toward overcoming the limitations of short-wave. A global, satellite carrier service could at least approach the reliability, quality, and audience focus of terrestrial VHF-FM broadcasting. It could be made resistant to undue interference, and it could be provided to the worldwide international, radio broadcasting community at a lower unit cost than ~~it~~ now pays for the lower-quality, short-wave broadcasts it delivers.

III. OBJECTIVES

An effective, global satellite service for international radio broadcasting must meet at least the best objectives that short-wave has offered, and in addition deliver the greatly increased reliability and quality via line-of-sight propagation directly to listeners' radios. RADIOSAT International's view of the satellite service objectives is derived, in part, from two related studies conducted for the Voice of America by the National Research Council of the National Academies of Sciences and Engineering in the United States. Two of our principals participated in these studies. The list of objectives represents our current, considered opinions, but we expect the list to evolve as we work with members of the international radio broadcasting community to develop a service compatible with their own objectives.

1. The service should be available to all countries on an equitable, common-carrier basis;

2. As with short-wave, any country would be able to broadcast directly to the people in all other countries on a reciprocal basis;

3. As with short-wave, the satellite service should be capable of providing global coverage to nearly all populated regions outside the Arctic and the Antarctic;

4. The service should be available to all the radio broadcasters, equitably, at the lowest unit price;

5. The basic program-channel service should be monophonic voice and stereo music, perhaps with various service grades, and possibly some novel, additional services;

6. There should be sufficient channel capacity to meet all of the needs of today's world-wide, public information/public diplomacy international radio broadcasters without mutual interference;

7. Signals should be able to focus strongly on some minimum audience area, with larger areas to be covered in multiples thereof;

8. Short- and long-term reliability should be excellent: at least equivalent to that offered in the United States and other developed countries by terrestrial VHF-FM broadcasting;

9. Vulnerability to natural or man-made interference should be noticeably less than that of short-wave transmissions of high effective radiated power;

10. As with short-wave, listeners should be able to receive broadcasts in the privacy of their homes; and

11. To meet mass market needs, a range of radio models of different performance characteristics and prices should be available with at least one having low initial and maintenance costs and easy operation.

IV. SYSTEM

The system concept envisions three satellites (Fig. 1) of very large antenna aperture in geostationary orbit. Each satellite will have multiple beams and power adequate to support at least 200 independent, monophonic voice channels and at least ~~14~~ 20 independent stereo music channels capable of the equivalent of good FM-multiplex quality. The satellites will be accessible from up-link earth stations which would be owned and operated by the individual international short-wave broadcasters. Network operations and control will be RADIOSAT International's responsibility. On-board processing in the satellites will facilitate program multiplexing and assignment to individual beams. The beams will be programmable and electronically steerable to ensure that the desired-language programs reach the geographic areas for which they are intended. If continuing discussions of their requirements with the international short-wave broadcasters show that some beams need to be fixed rather than steered, a simplification of the feed, onboard processing, and beam switching and steering will result. Power will be sufficient to overcome spacecraft incidental operating losses, losses to foliage, and losses to building penetration in most cases. An additional margin will be built in to accommodate a 6dB power augmentation for 20% of the

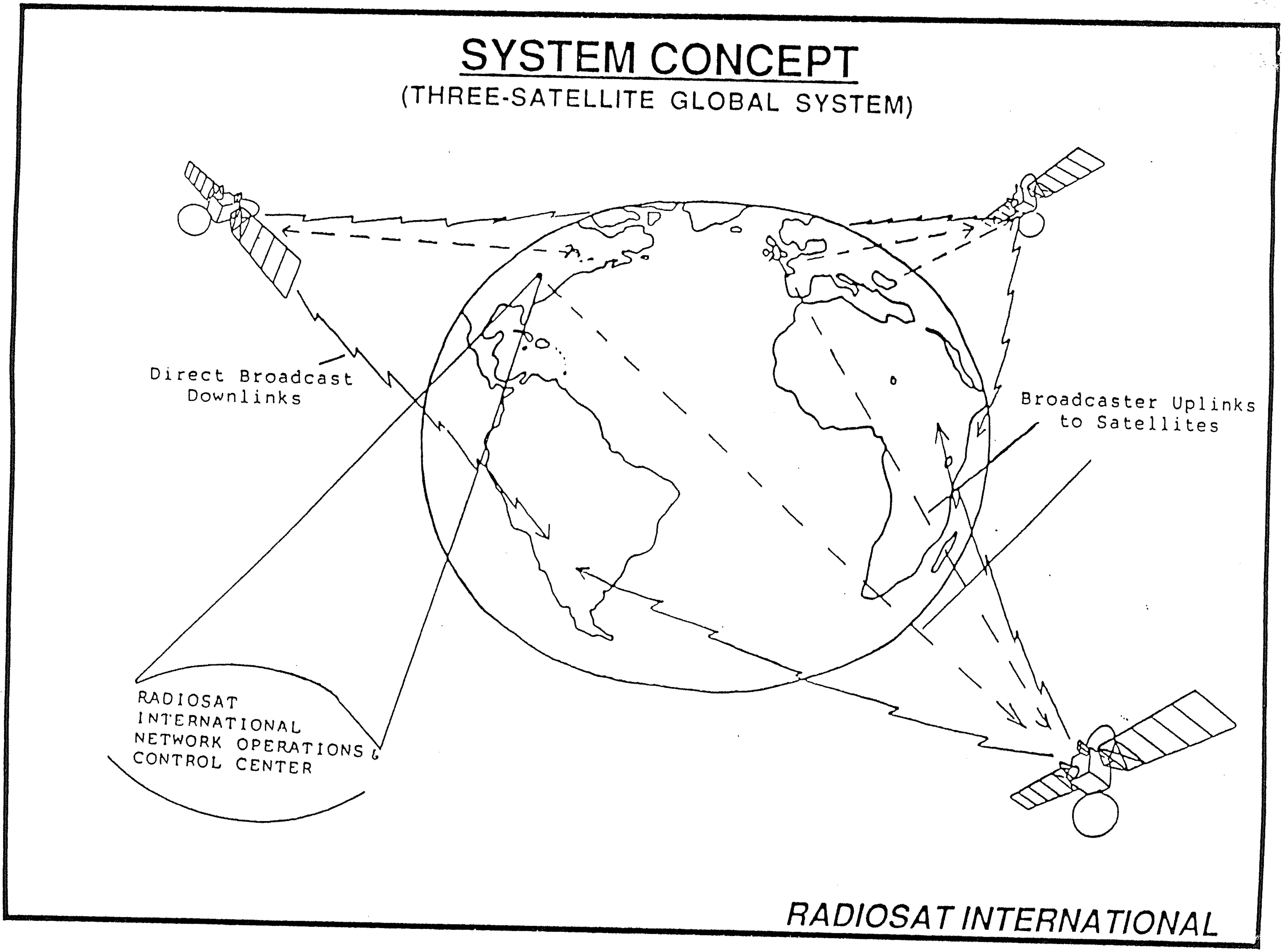

SYSTEM CONCEPT
(THREE-SATELLITE GLOBAL SYSTEM)
Direct Broadcast Downlinks
Broadcaster Uplinks to Satellites
RADIOSAT INTERNATIONAL NETWORK OPERATIONS & CONTROL CENTER
RADIOSAT INTERNATIONAL

Figure 1

channels if that is needed, for example in cases of excess building losses. Downlink broadcasting will be direct to listeners' radios (Fig. 2).

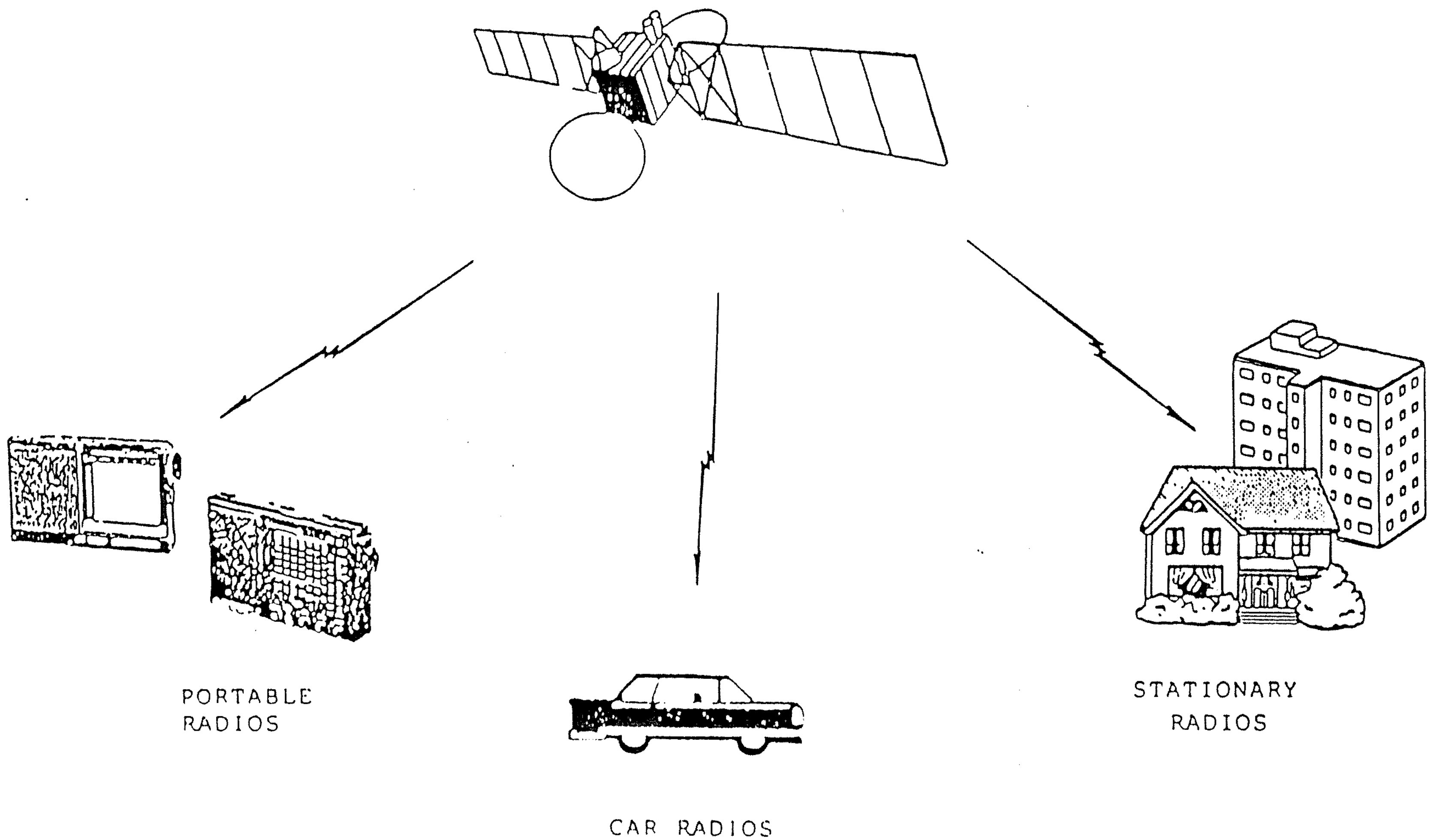
Table 1, System Characteristics, shows the gross system parameters. The source coding and compression schemes have not been selected yet: several, including MASCAM/MUSICAM, are under consideration. The assumption base for these characteristics follows.

1. Antenna: International radio broadcasters want to maximize their audience populations with direct-to-listeners broadcasts, meeting objectives like those discussed above, at minimum cost. The greatest audience coverage can be found in and around major population centers. Since large channel capacity must be available in the satellites to provide equitable access to all international broadcasters desiring satellite carriage, this means not only high effective radiated power per program channel in the satellite, but also large, total power requirements to satisfy all comers. Tradeoffs between antenna gain and real power suggested antenna aperture values of 50m and 28m, with per-beam area coverages of about 25,900 km^2 (9330 mi^2) and 82,600 km^2 (29,700 mi^2) respectively, at satellite nadir. Thus, some population well outside the limits of urban population centers would be covered within a beam. Although rural populations might not be unless particular coverage from a spot beam were desired for them, RADIOSAT International has been led to believe through discussions with some of the international broadcasters that they might weigh less in the tradeoff balance than the potential increase in audience share achievable through improved quality, reliability, and availability of service to the urban population centers and their surroundings. At 28 the nadir area coverage is essentially equivalent to covering a geographically small country such as Austria, or Belgium, the Netherlands, and Luxembourg together. The choice of aperture is then reduced to one of minimizing the total weight of antenna subsystem, power amplifiers, and power subsystem in the satellite.

2. Number of Beams: This number is an early extrapolation based on broadcasting schedules and country coverage requirements of some of the major, international, short-wave broadcasters. RADIOSAT International intends to develop details of its networking, system coverage characteristics, and on-board channel multiplexing and beam management through detailed planning with the broadcasters. That will ensure that the system is truly compatible with their requirements while RADIOSAT International focuses on a more accurate determination of the number of beams required.

3. Margins: To meet the objective of broadcasting direct to listeners' radios, EIRP sufficient to cover losses caused by foliage screening and buildings must be provided. Initially, we used data in CCIR Report 955-1 (Mod F), Appendix 1, to arrive at the values shown, adding

DIRECT BROADCAST TO RADIOS



RADIOSAT INTERNATIONAL

Figure 2

SYSTEM CHARACTERISTICS

SATELLITES

- 10-YEAR OPERATING LIFE IN ORBIT
- ANTENNA APERTURE - 28 - 50 meters
- ~ 50 SEPARATE BEAMS: STEERABLE; INPUTS SWITCHABLE
- MARGINS FROM 3-DB POINTS:
  - Foliage 12 dB
  - Buildings 15 dB
  - Incidental losses 2.5 dB
  - Power augmentation (20% of beams) 2 dB
- SIGNAL PROCESSING - EBU/EUREKA 147 SYSTEM
- END-OF-LIFE DC POWER - 2-6.2 kW
- VERIFIABLE STATE-of-the-ART TECHNOLOGIES

RADIOS

- LISTENER OWNED
- SELL FOR $50-60
- TELESCOPING ANTENNA, 13-15 dB GAIN

PREFERRED FREQUENCY - 1.429 - 1.525 GHz

UP-LINK EARTH STATIONS - BROADCASTER-OWNED

Table 1

RADIOSAT INTERNATIONAL

them together to ensure that sufficient spacecraft radiated power would be provided to overcome combined losses in over 95 percent of cases. Subsequently, a CCIR Fact Sheet[1] reporting results and analysis of propagation experiments conducted by the NASA Ames Research Center and the University of Texas at Austin indicated that it is probably not necessary to add foliage and building losses together, and that over 90% of cases of shadowing and losses in tall buildings would be quite adequately covered with a margin of 20, not 27, dB. Moreover, the Fact Sheet showed a periodic structure of fades within buildings with a trough-to-crest distance of 30-50 cm independent of direction and decreasing as losses increased. These results are only weakly dependent on frequency. The periodic structure is stationary at any frequency as long as the source is stationary, so that moving a portable receiver less than 50 cm or so could result in loss mitigations of four to six dB. Thus, the losses assumed initially, as shown in Table 1, may be reduced on average by 7-10 dB while still covering over 90, and perhaps 95, percent of cases. We have chosen a conservative reduction of 7 dB. We shall return to this in Section V, Link Analysis.

In addition, provision is made for augmenting the power supplied to 20% of the beams by 6dB for those few, remaining cases in which the margins may still prove inadequate. As it is unlikely to find cases in which maximum foliage shadowing occurs in the line of sight to tall buildings in urban areas, where the building losses average 12-15 dB, these margin provisions are deemed adequate to meet the broadcasting objective. Moreover, incidental losses of 2.5 dB are ascribed to spacecraft and earth station construction and operation; a very conservative number compared with the 1.5-2.0 dB experienced with many satellite communications systems and in the ATS-6 program.

All these margins have been added together to determine the transmitter power required in the spacecraft.

4. Signal Processing: Versions of several signal processing systems have been reported in the literature and to the CCIR. The Eureka-147 system and an all-digital system currently designated Advanced Digital System III are the most prominent. But, to the best of RADIOSAT International's ability to determine as of July 1991, only the Eureka-147 system has been developed to the point of modification and refinement resulting from several successful field trials. Our approach to fielding an operational, common-carriage-like satellite system is to use proven technologies everywhere possible. Like the preponderance of radio broadcasters around the world, RADIOSAT International regards digital audio broadcasting as the preferred approach for future systems. Thus Eureka-147 is the current system choice. Calculations

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1 CCIR FACT SHEET: Draft Revision of the Consolidated Report of JIWP 10-11/1 and JIWP 10-11/3 to JIWP WARC-92; John Kiebler; January 29, 1991.

are based on the parameters of Eureka-147 as we understand it and on an initial sizing of each satellite for 200 program channels of CD-stereo-equivalent quality. Bandwidth and bit-rate modifications to recognize program requirements of the international, short-wave broadcasters, departing from the extreme demands of CD-stereo quality, will be discussed later, in Section V.3.

RADIOSAT International has seen source coding and compression schemes in both industrial and university laboratories that reduce standard, 64kb/s telephone voice signals to codes of 16kb/s and reproduce the voice signals at the receiving end with little or no audible impairments. These laboratories are now working on coding and compression schemes for good, monophonic, FM voice signals of 7.5kHz baseband with a goal of 40 kb/s maximum and little or no impairments. Parallel work is under way in coding of music equivalent to the best stereo FM-multiplex. Results are expected for voice coding at the end of September 1991; for music, in December. The choice of source code and compression scheme will be made after comparison testing of these and MASCAM/MUSICAM, perhaps in the early part of 1992.

5. <u>End-of-life D-C Power:</u> Initial link calculations showed power requirements of 6 and 10 kw, respectively, for the 50m and 28m apertures. Reductions to less than 0.4 and 1.2 kw, respectively, are possible if more realistic assumptions are made about the actual losses and the bandwidths and coding rates required for carriage of the international, short-wave broadcasters' program materials than CD-stereo for all program channels. These changed assumptions will be discussed in Section V, <u>Link Analysis</u>, but the end results for EOL d-c power are shown in Table 2. All calculations are based on an all-up satellite efficiency of 25%, a figure obtained in discussions with a prominent communications satellite manufacturer.

6. <u>State-of-the-Art Technologies:</u> Discussions with satellite manufacturers in Europe and the United States have verified that the technologies planned for use in RADIOSAT International's global satellite fleet are technically feasible within the planned timeframe and that the project is doable in that timeframe. All technologies but one will have been flown before launch of RADIOSAT I at the end of 1995. That one, the large-aperture antenna, is not deemed to be unusually risky for several reasons. First, one European and one American manufacturer have technologies, or access to technologies, of lightweight, deployable antennas based in part on proven deployment techniques. Second, even at 50m the aperture-to-wavelength ratio of 250 at 1.5 GHz is not very much greater than the ratio of over 230 exhibited by NASA's ACTS satellite at K_a band, to be flown in 1993. This suggests that satisfactorily tight tolerances in conformity to the theoretical paraboloid are already with the state of the art. Third, structural models of reliable deployment mechanisms

for aperture structures up to 55m have been built and exercised in laboratories since 1984 [CCIR Report 955-1 (ModF), Annex I], and work is now continuing. And last, since 6 kw spacecraft power-supply systems are well within today's state of the art, the RADIOSAT International system will focus on the 28m, rather than the 50m, aperture, substantially relieving mechanical stress problems of antenna deployment structures and reflector rigidity, in turn making schedules easier to achieve.

7. Radios: The objectives of Section III imply strongly that the radios used to receive broadcasts from RADIOSAT International's satellites will be listener-owned. Although there are short-wave radios available, e.g., from the People's Republic of China, for $8-$10 U.S., it is unlikely that L-band radios can be made for that price. Discussions with radio receiver manufacturers in the U.S. and Europe, however, have tended to verify the manufacturability of listener-owned radios to sell for $50-$60 U.S. That price range is the current, low-end, catalog price of multi-band, short-wave radios available in mail-order catalogs from U.S. suppliers and manufactured in several countries around the world. Based on some audience research studies by the VOA, it appears that listeners over much of the world are eager for news and comment from countries other than their own, and many put sufficiently high priority on such program material that they are willing to pay prices in that range. If they will do that for the poor quality and reliability of short-wave, they will surely do it for replacement L-band radios when the improvement in quality of the satellite signal is perceived. That improvement must be demonstrated in precursor experiments, which will be treated in Section VIII.

The radio antennas are conceived of as folding and telescoping, much like today's whip antennas in radios and television receivers. Preliminary calculations suggest that such an antenna, having 13-15 db gain, can be made a part of the radio within the sale price range.

8. Up-link Earth Stations: RADIOSAT International plans to have each international broadcaster desiring carriage on its satellites own and operate its own earth station. Our plans include working with each broadcaster to specify the earth stations for optimum compatibility with its needs and the satellite system. If need be, we will assist broadcasters in acquiring their earth stations. Networking and operations control will be performed at the RADIOSAT International Network Operations and Control Center, but each broadcaster will be assured of its access to the satellite system through ownership and operation of its own earth station(s).

V. LINK ANALYSIS: THE L-BAND/S-BAND CONTROVERSY

1. Background: An allocation of radio-frequency spectrum for satellite sound broadcasting has been under study since 1979. Resolution 505

of WARC-79 encouraged experimentation with a broadcasting satellite services (sound) in portions of the spectrum between 0.5 and 2 GHz, suggesting the 1.429-1.525 GHz region as a likely place for such an allocation. WARC-ORB-88 expanded the region of possible allocation to an upper limit of 3 GHz. It is recommended that experimentation take place in the 1.429-1.525 GHz band after considering the data available on propagation and the effects of frequency allocation choices on satellite design, feasibility of construction and possible costs.

The international short-wave broadcasters adopted a recommendation unanimously to allocate the 1.429-1.525 GHz L-band to BSS (sound) at their preparatory meeting for WARC-92 in Sydney, Australia in December, 1990. Other interests in various administrations have opposed this allocation, recommending various parts of the S-band spectrum: 2.31-2.37 GHz, or the band of 2.5-2.69 GHz already allocated to the BSS.

Various approaches to comparative link analyses have shown that, for equal capacity, coverage, and performance, S-band allocations present anywhere from 5.5 dB to 11-12 dB greater losses than L-band allocations. Under VOA auspices, NASA conducted a study whose results were first presented at the CITEL meeting in Washington in May, 1991, showing that for equal capacity, coverage, and performance three S-band satellites are required to do the work of one L-band satellite.[2] Using propagation data and some preliminary information supplied by NASA, RADIOSAT International and other proponents of BSS (sound) showed a disadvantage of at least 5.5 dB and perhaps closer to 6 dB for an S-band allocation at about 2.3 GHz compared to the L-band allocation at about 1.5. The arguments are summarized in Figure 3. Notice that Figure 4, developed by NASA from its own data, suggests approximately a 10 dB increase in losses of "Advanced Digital Systems" at 2.34 GHz compared with those at 1.5.

In June 1991, defining the United States posture for WARC-92 regarding this issue, the Federal Communications Commission ruled that it would allocate some spectrum for BSS (sound) about 1.5 GHz and some in the S-band region between 2.31 and 2.37 GHz. The amount of spectrum remains to be determined as of July 1991.

2. Link Analysis: Table 2 shows a link analysis in which satellite power is the parameter to be determined. Downlink determinations are made at 1.5 GHz for 50m and 28m antenna apertures, and at 2.34 GHz, the center of the proposed S-band allocation, for apertures of identical beamwidth (and therefore surface coverage). Radio antenna gain of 15 dB is assumed for 1.5 GHz transmission; at 2.34 GHz the

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2 *Direct Satellite Sound Broadcasting, System Tradeoff Study*; Nasser Golshan, Jet Propulsion Laboratory, California Institute of Technology; May, 1991.

WHY L-BAND?

- LOSSES ABOUT EQUAL at UHF and L-band, SHARPLY INCREASED at S-band.
  >6dB higher at/above 2.3 GHz.

- SPACECRAFT FOR RADIO BROADCASTING become ungainly and expensive below L-band -- INCREASING COSTS perhaps 2:1

- >6dB LOSSES (Factor of 4 or greater) mean >6dB MORE POWER, which means >6dB HIGHER COSTS.

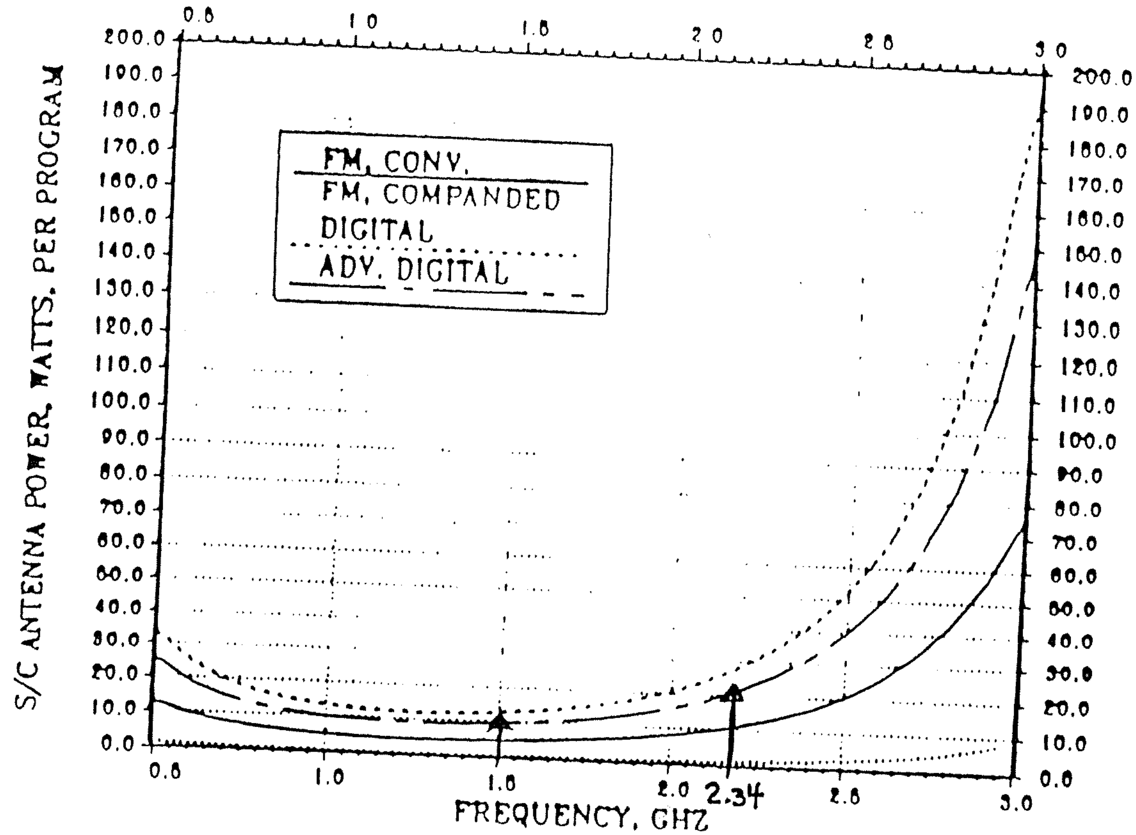
- RESULT COULD BE TOO-COSTLY SERVICE PRICED OUT OF EMBRYONIC MARKET.

- IN ADDITION, POPULATION OF INDUSTRIAL, SCIENTIFIC, and MEDICAL INSTRUMENTS FROM 2.350 - 2.400 GHz PRECLUDE SATISFACTORY OPERATION OF BSS-SOUND

Figure 3

RADIOSAT INTERNATIONAL

SATELLITE TRANSMIT POWER VS. FREQUENCY REQUIRED TO MAINTAIN EIRP VALUES AT 1° CONTOUR



RADIOSAT INTERNATIONAL

Figure 4

LINK ANALYSIS

	L-Band (1.5 GHz)			S-Band (2.34 Ghz)	
Antenna	50 m	28m		32m	17.9m
Beamwidth	0.28°	0.5°		0.28°	0.5°
On-axis gain @ 65%	56 dB	51dB		56dB	51dB
@ 3 dB points	53 dB	48dB		53dB	48dB
Space loss at coverage limits	-188.8dB			-192.5dB	
Rcv antenna gain	15dB			18.9dB	
Rcv antenna aperture	44.5cm			44.5cm	
Loss margins					
Foliage	-12dB			-13dB	
Buildings	-15dB			-21dB	
Implementation			-2.5dB		
20%, 6dB power augmentation			-2dB		
Total losses after CCIR Fact Sheet			-24.5dB		
System noise			238K		
kT			-204.9dB		
E_b/N_o			8.5dB		
R_b			72 dB		
P (20MHz)[dB]	20.8dB	25.8 dB		28.7dB	33.7dB
[kW]	0.12kw	0.38kw		0.741kw	2.34kw
EOL pwr @ 25% [kW]	0.481kw	1.52kw		2.97kw	9.38kw

Table 2

RADIOSAT INTERNATIONAL

radio antenna <u>size</u> is held constant so that the increased gain compensates for the increased space loss.

Margins of 12 dB for foliage losses and 15 dB more for building losses at L-band are combined as discussed in Section IV.3. The increases of 1 dB for foliage and 6 dB for building penetration at S-band are taken from reference 1, previously cited, and a contribution of John Kiebler, author of reference 1, to the deliberations of U.S. Interim Working Group 2 of the FCC's Industry Advisory Committee preparing for WARC-92. Noise temperature is derived from a 1 dB noise figure, achievable in the radios at L-band and probably at S-band, and following the model of CCIR Document JIWP 10-11/1-63E (Corr. 1), 9 January 1991. E_b/N_o is also taken from that document, accepting the value chosen by Eureka-147 and Alard and Lassalle's[3] arguments favoring differential over coherent detection.

Consistent with the assumption of Eureka-147, the bit rate chosen initially for the link is based on the useful bit rate in JIWP 10-11/1-63E, 2.8 Mb/sec in 3.5 MHz. For our purposes 4 MHz blocks of bandwidth are used, bringing the bit rate up to 3.2 Mb/s per 4 MHz block. The VOA has estimated a 20 MHz requirement for international radio broadcasting, so five times the 4MHz bit rate yields 16 Mb/s. Results of Table 2 suggest that S-band spacecraft for the global, international, radio broadcasting application could require power supplies beyond the state of the art if the coverage increases beyond that provided by 0.5° beamwidth, but the L-band ones do not.

3. <u>Actual Bandwidth Requirements:</u> Table 2 shows the power required for the 20 MHz bandwidth both for the transmitter and for satellite [redacted] end-of-life d-c. Since the presentation of CD-stereo quality capability far exceeds the needs of international broadcasters, most of whom broadcast 80-85% monophonic voice, reductions in bandwidth and bit rate corresponding to actual services must be considered. The effects of bandwidth and bit-rate reductions accompanying the international broadcasters' operating requirements are significant.

To ensure a signal quality enhancement that is likely to capture and keep listeners' attention, not just initially but likely over many years, RADIOSAT International has assumed good FM quality, for both monophonic voice and stereo-multiplexed music programs. We are not convinced of the necessity of broadcasting "CD-stereo" quality, with its dynamic range exceeding 96 dB, into small radios that cannot possibly reproduce that dynamic range or cope convincingly with a 20 kHz audio bandwidth, regardless of whether the radios are in relatively

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3 "Principles of Modulation and Channel Coding for Digital Broadcasting for Mobile Receivers;" Alard, M. and Lassalle, R. <u>Advanced Digital Techniques for UHF Satellite Sound Broadcasting</u>; EBU, August, 1988.

quiet, residential environments or in the noisy environments of mobiles. Thus, basebands of 7.5 kHz for monophonic voice and 15 kHz for stereo-multiplexed music provide the basis for our calculations.

Using the 220 kb/s per coded CD-stereo program channel of 20kHz baseband in JIWP 10-11/1-63E, the baseband reductions yield bit rates of 41.25 kb/s for monophonic voice and 165 kb/s for stereo-MPX music. If the 180 kb/s rate for CD-stereo is used, the reduced bit rates become 33.75 and 135 kb/s, respectively. We need to examine the channel capacity of a 4MHz block to determine what further power reductions can be achieved.

We assume that music broadcasts occupy 16-20% of the broadcasting time. For a 4MHz block of spectrum, we use the 3.2 Mb/s bit rate. And we have assumed the bit-rate format of JIWP 10-11/1-63E. Using the Advanced Digital System II information bit rates of 150 and 100 kb/s together with single-side, CD-stereo equivalent rates of 110 and 90 kb/s respectively, and applying the bit-rate reductions above, we find (Table 3) a possible channel capacity of 207 voice and 22 music channels in four 4 MHz blocks at 110 kb/s rate, or 256 voice and 27 music channels at the 90 kb/s rate. Details of channel capacity per satellite and the desired program bit rate remain to be worked out together with the broadcasters, but it seems safe to say that 16, rather than 20, MHz of bandwidth will be more than adequate at the 110 kb/s rate and that 12, rather than 20, might well suffice at the 90 kb/s rate.

CHANNEL CAPACITY

Single-side bit rate	110 kb/s	90 kb/s
Total bit rate	3.2 Mb/s	3.2 Mb/s
Data bit rate	150 kb/s	100 kb/s
Useful program bit rate	3.05 Mb/s	3.1 Mb/s
Monophonic voice rate	41.25 kb/s	33.75 kb/s
Voice channels @ 70% capacity	51 + [.75]	64 + [.2]
FM-stereo-MPX rate	165 kb/s	135 kb/s
# Music channels	5 + [.54]	6 + [.89]

Table 3

Thus, power reductions for realistic assumptions of program bandwidth and bit-rate requirements for the international broadcasters could provide (Table 4) much more tractable power requirements at L-band, while still presenting much larger power supply requirements at S-band.

POWER LEVELS FOR REDUCED PROGRAM BASEBANDS

Frequency	1.5 GHz		2.34 GHz	
Antenna	50 m	28 m	32 m	17.9 m
	110 kb/s single-side rate			
Pt	0.096 kw	0.304 kw	0.592 kw	1.872 kw
EOL Power @ 25%	0.384 kw	1.22 kw	2.37 kw	7.49 kw
	90 kb/s single-side rate			
Pt	0.072 kw	0.228 kw	0.444 kw	1.41 kw
EOL Power @ 25%	0.29 kw	0.91 kw	1.78 kw	5.62 kw

Table 4

4. Reduced Antenna Apertures: It is clear from Table 4 that additions and reductions can be taken in the antenna aperture at L-band while keeping the power supplies within today's state of the art. Power supplies of 6 kw, and even 10, were in production at one satellite manufacturer's facilities by December 1990. To remain conservative, a gain reduction of about 6 dB, less than the margin reduction suggested by the CCIR Fact Sheet[4], would permit an L-band aperture as small as 14m. With such an aperture the EOL power becomes 4.9 kw for the 110 kb/s single-side rate, or 3.64 kw for the 90 kb/s rate.

More importantly, since the power supplies do not present problems at L-band, the footprint now becomes 330,400 km^2 (118,800 mi^2), allowing much greater earth coverage per beam and significantly increased national coverages with 50 beams.

As can be seen from Table 4, this does not apply at S-band, where the EOL power requirement at 0.5^o coverage, equivalent to that of the 28m aperture at L-band, is already near the edge of the state of the art.

5. Multiple-Hop Considerations: There remains the question of multiple-hop transmissions and their cost in power. RADIOSAT International's plans are based on a maximum fill of 80% for any satellite. Whether this fill level includes multiple hop depends upon the development of detailed traffic requirements with the broadcasters. In any case, the satellites have been sized for power to

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4 CCIR FACT SHEET, ref. cit. p. 5.

satisfy full fill, so that 20% of the power could be available, if needed, for multiple-hop. We believe that number to be conservative.

The issue is whether to accomplish multiple-hop transmission by direct satellite-to-satellite crosslink or by conventional double hopping to the surface. The latter can certainly be satisfied by the power reserve of 20% from maximum expected fill to full fill. At 20%, the bandwidth for crosslinking will be 3.2 MHz. We have calculated the power requirements for a 4MHz block of spectrum at about 43 GHz, and have assumed equiangular spacing of the satellites, giving a line-of-sight range of 55,280 km. We have assumed a 6 dB noise figure for the satellite receiving system and antenna sizes of 0.2 m. The crosslink beamwidths at both ends are 2.44^{o}, presenting little or no tracking problems, and if the carrier level is 30 dB the additional power required is less than 4 w r-f, equivalent to less than 15 w end-of-life d-c. At the satellite power levels required for full capacity this is insignificant, and the decision between crosslinking and surface-based double-hopping will be made together with the broadcasters on non-technical considerations.

6. Power backoff: The problem of minimizing distortion in transmitting numbers of carriers through a single power amplifier is well known. Common practice in satellite communications is to backoff from the knee of the power curve to take advantage of the linear portion of the transmitter characteristic, minimizing the distorting effects of higher-order Taylor-series terms in the output-input characteristic representation. The backoff penalty with 448 carriers of Eureka-147 may be too great. Current practice in satellite communications with single-channel-per-carrier transmissions is about 6 dB to get satisfactorily down on the linear portion of the power transfer characteristic. However, another approach, very familiar to short-wave broadcasters, may prove fruitful. That is to reciprocate the output power transfer characteristic at a low power level in the drive circuits, predistorting the multiple-carrier drive to the power amplifier so that the output characteristic tends to cancel it out. We have not yet investigated the details, but the approach sounds sufficiently promising to warrant such investigation. We understand it to be effective for bandwidths less than 36MHz. Should this approach show promise of relieving the need for backoff, consideration could then be given to reducing the L-band aperture further or to reducing the power requirements or radio receiver antenna gain.

VI. ANTENNA TECHNOLOGIES

Large-aperture antennas on spacecraft require exceptionally light-weight materials and must be deployed in orbit because of space limitations of launch-rocket shrouds. Conventionally, approaches to such requirements have involved reflective meshes suspended on deployable ribs that have been fabricated to provide the correct paraboloidal curvature for the deployed antenna. The successful, wrap-rib construction of the 9m antenna of ATS-6 was chosen for its simplicity and reliability: in laboratory deployment tests articulated, multi-joint, parasol-like structures failed catastrophically and in some cases failed to open, while the wrap-rib design opened repeatedly. For apertures of 20m or greater it may be necessary to provide single-joint, single-fold ribs, a concept currently under development.

Matching the thermal coefficients of expansion of ribs and mesh is fundamental to achieving the proper curvature for the antenna. This problem has been solved by choosing materials with coefficients of equal magnitude and opposite sign.

Preliminary estimates of one antenna manufacturer, based on extensions of the ATS-6 technology, indicate that a 28m aperture can be made with 14 single-joint ribs and a maximum curvature tolerance of 0.16 cm at 1.5 GHz, where the wavelength is 0.2 m or 1250 times the tolerance. This is near-perfect for antenna applications. Such an antenna, including deployment mechanism, would have a mass of about 568 kg and could be delivered within RADIOSAT International's schedules.

Other technologies such as thermal-curing inflatables have also been examined, but their developers do not feel they are sufficiently mature to attempt the RADIOSAT International application.

VII. COVERAGE ENVELOPE

RADIOSAT International plans to offer its services with three satellites; one each stationed over of the Atlantic, Indian and Pacific Oceans. Coverage envelopes have been calculated for the "Atlantic" satellite for minimum elevation angles of 20°, 15°, and 10° and a satellite station at 20° W. longitude. For a minimum elevation angle of 15°, the envelope goes over 70° N. latitude in Europe and as far east as Ulyanovsk and Baku, at about 50° E. longitude. It covers the Middle East except for Iran, which falls well within the envelope of the "Indian Ocean" satellite. Middle Eastern coverage of the "Atlantic" satellite goes as far east as 65.2° E. longitude. The coverage envelope includes all Africa, all South America, Central America to Villahermosa, Mexico, about 73° W. longitude, the Eastern and Central time zones of the U.S. to 90° W. longitude, and Canada to 85° W. longitude. From a station at about 100° E. longitude, the "Indian Ocean" satellite coverage includes eastern Russia, South Asia, the Orient and Australia; the "Pacific" satellite provides coverage of the western parts of North and Central America. Coverage envelopes will shift if the satellite stations are changed. The actual stations applied for will be determined through traffic and coverage requirements studies with the international broadcasters. One broadcaster has already established a strong preference for launching the "Indian Ocean" satellite before the "Pacific" satellite. Preliminary investigations confirm this preference to be valid for our system.

VIII. EXPERIMENTS

RADIOSAT International has entered into a relationship with a U.S. terrestrial broadcaster to conduct experiments in digital audio broadcasting some two years before launch of the "Atlantic" satellite. These experiments are intended to involve radio manufacturers, and, among other things, will compare different baseband coding and compression schemes, signal-processing schemes other than Eureka 147 if any are sufficiently well developed in time for the experiment series, and simulated approaches to satellite onboard processing and beam-switching and -steering. Participating radio manufacturers will be involved in the data evaluation and will have high-visibility exposure of their products to consumer audiences well in advance of first launch. We anticipate that their participation in the design of these experiments, and in a companion set of experiments using NASA's ACTS satellite, could lead to radio designs in which large parts of the experimental radio sets would be retained in the production radios to work with RADIOSAT International's satellites. We believe the VOA and NASA will be involved in the experiment series, which are planned to take place in 1993.

IX. SCHEDULES

The experiment series will begin in 1993 and continue during 1994 and 1995. RADIOSAT International plans to launch the Atlantic satellite at the end of 1995, the Indian Ocean satellite at the end of 1996, and the Pacific satellite at the end of 1997. The Atlantic satellite will either be replaced or supplemented by the first-generation ground spare in about 2003, and work is planned to begin on the second-generation spacecraft in 1998-99. This is consistent with an eight-year depreciation cycle for spacecraft designed for 10-year life in orbit.

Operations in orbit are planned to begin early in 1996.

X. CONCLUSION

A global satellite system operating at L-band will offer equitable access on a common-carrier-like basis to the international, short-wave broadcasters. The satellites will each carry 200 channels of FM-monophonic quality voice and at least 15 of FM-stereo-multiplex quality music. Antenna apertures of 14-20 m with 50 steerable spot beams permit the satellites to work directly into listener-owned radios priced competitively with today's multi-band, short-wave radios. Broadcasters will own and operate their own up-link stations, and traffic distribution will be determined through joint efforts between RADIOSAT International and the broadcasters. First launch, planned for 1995, will permit satellite broadcasting operations to begin in 1996. Precursor demonstration experiments involving radio manufacturers will begin in 1993, providing early market visibility for radio sets compatible with the satellite system.