ALTERNATIVES FOR SATELLITE SOUND BROADCAST SYSTEMS AT HF AND VHF

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NASA and the United States Information Agency (USIA) are currently engaged in a joint program to assess the technical and economic feasibility of direct sound broadcast satellite systems to meet USIA mission needs. A Memorandum of Agreement (MOA) initiating the activity was signed by the Agency administrators in March of 1983. The MOA calls for a series of interrelated studies to provide the respective Agency managements with information on the potential role of direct broadcast satellites. As shown in figure 1, initial studies focused on HF propagation phenomena and broadcast coverage requirements. These studies, completed in early 1984, served as the basis for parallel systems studies currently in progress. The systems studies are to provide a data base on various satellite configurations and systems concepts capable of supporting potential broadcast requirements ranging from a small fraction to a substantial addition to USIA requirements. NASA LeRC is managing the systems study contracts (TRW and Martin Marietta), which will be completed in mid 1985. NASA LeRC is supporting USIA/Voice of America in the assessment of future receiver populations and the cost effectiveness study.

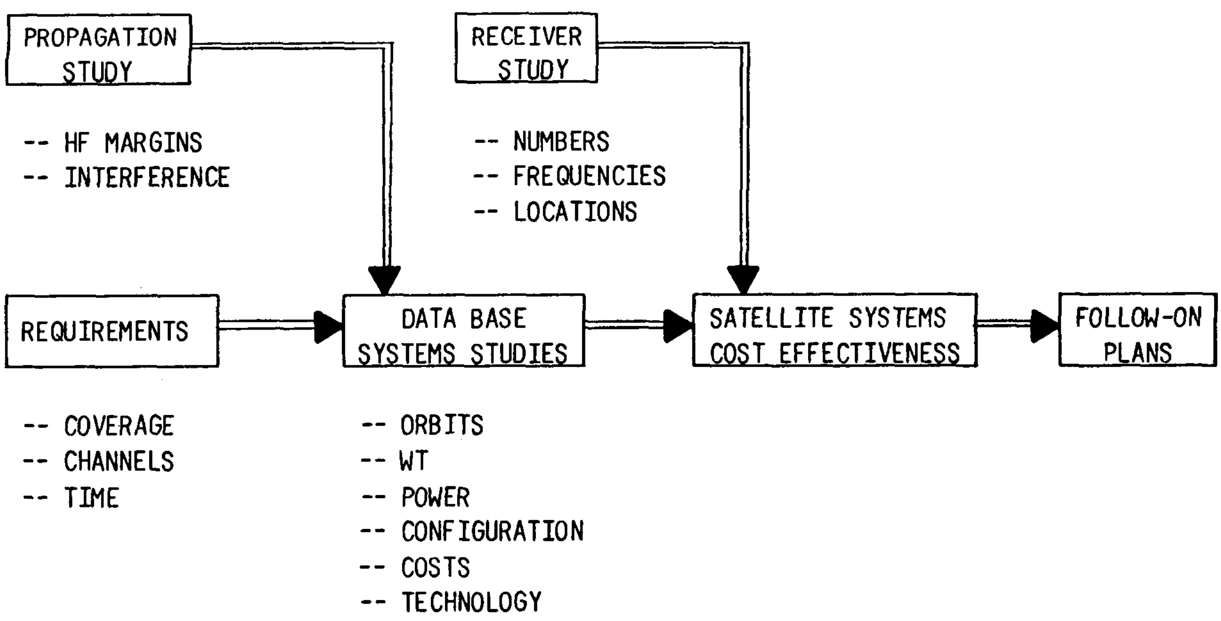


Figure 1. Phased program approach.

The scope of the data base systems studies is quite large, covering systems operating at HF (15 - 26 MHz), VHF (60 MHz), L-band (1.5 GHz), and Ku-band (12 GHz). Geographical coverage ranges from single small countries to nearly worldwide. Except for Ku-band, power requirements vary over two orders of magnitude, and consequently, low Earth orbits (LEO) are considered for the lower frequency systems where launch constraints prohibit geostationary satellites.

Figures 2 and 3 indicate typical link parameters for HF and VHF geostationary satellites. Under the assumptions indicated, a net transmit power of 10 kW into a 270 m apperture is required to produce a single audio channel in a 3^{0} beam at 26 MHz. Under normal conditions, such a signal is of "reasonable" quality when received by a commercial grade receiver in suburban areas. If ionospheric scintillation is present, however, deep fades may occur which render the signal useless. At VHF, power and antenna requirements are halved and scintillation is much less a problem.

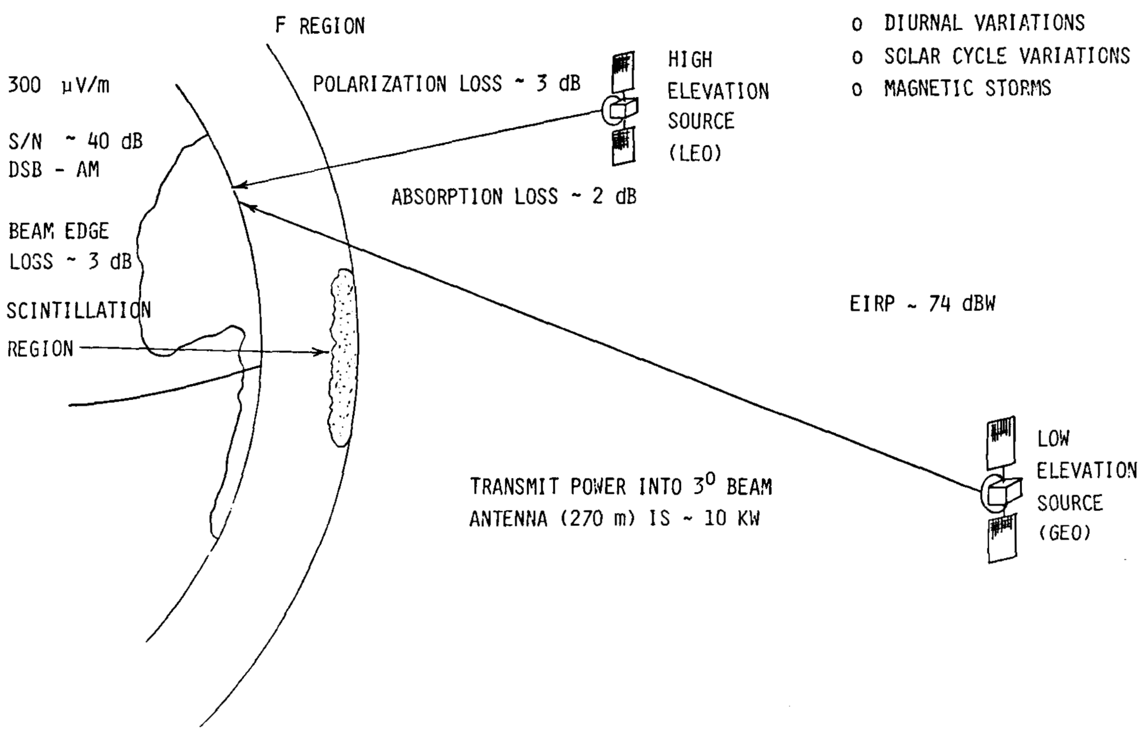


Figure 2. HF link analysis (26 MHz).

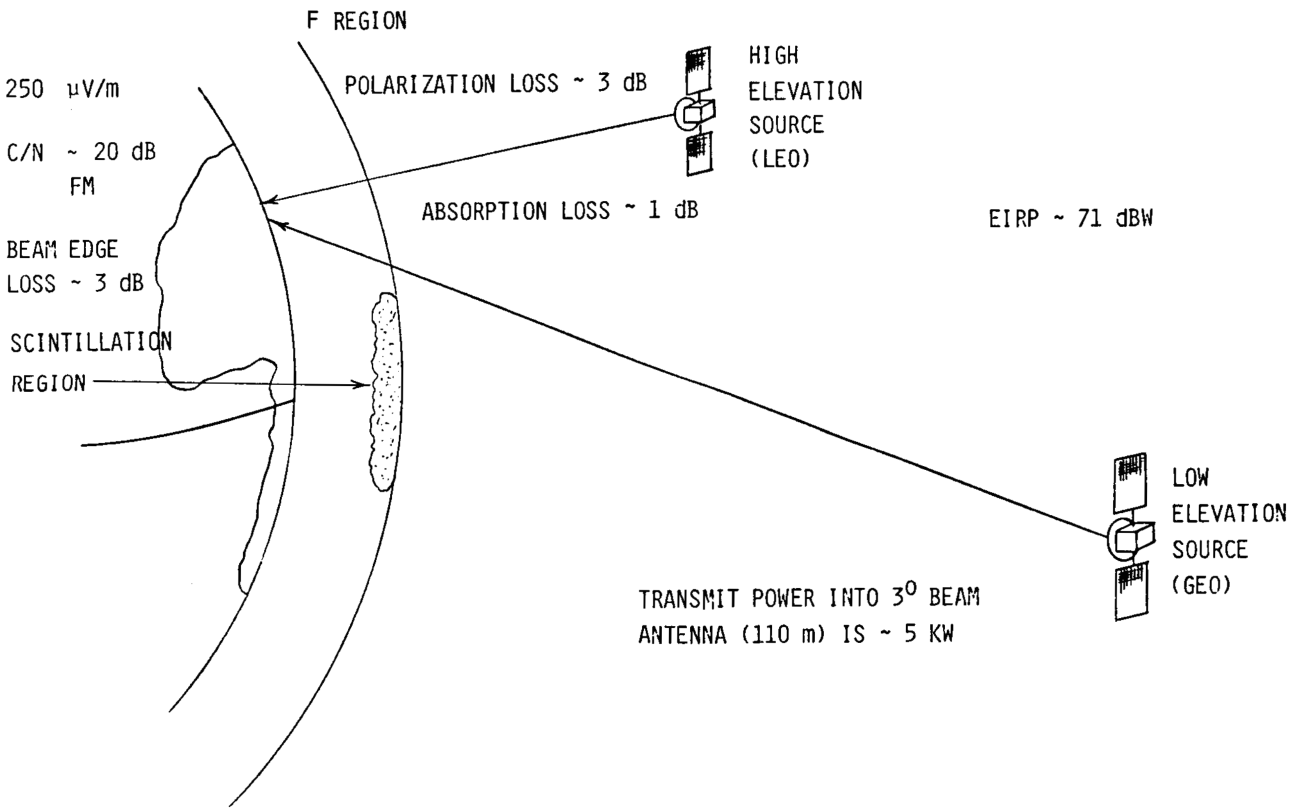


Figure 3. VHF link analysis (60 MHz).

For both HF and VHF systems, LEO and GEO orbits present distinct advantages and disadvantages. While GEO orbits permit continuous contact with the target broadcast area, ease of program uplink, and manageable solar array degradation, such orbits also require extremely large antennas, may not be capable of providing a signal to latitudes beyond $\pm$ 50°, and due to launch constraints, have very little capacity. Alternatively, inclined low Earth orbits permit smaller antennas, increased channel capacity per satellite, and can cover all latitudes. However, the use of such orbits presents operational problems in uplinking program material, steering broadcast beams and solar arrays to the desired orientations, allows only limited contact time, and presents a more severe radiation environment. These general trends are depicted in figures 4 and 5. Note that for constant area coverage, broadcast power is a constant. Note also that while LEO orbits require a smaller antenna, they require more prime power than GEO orbits due to radiation damage effects.

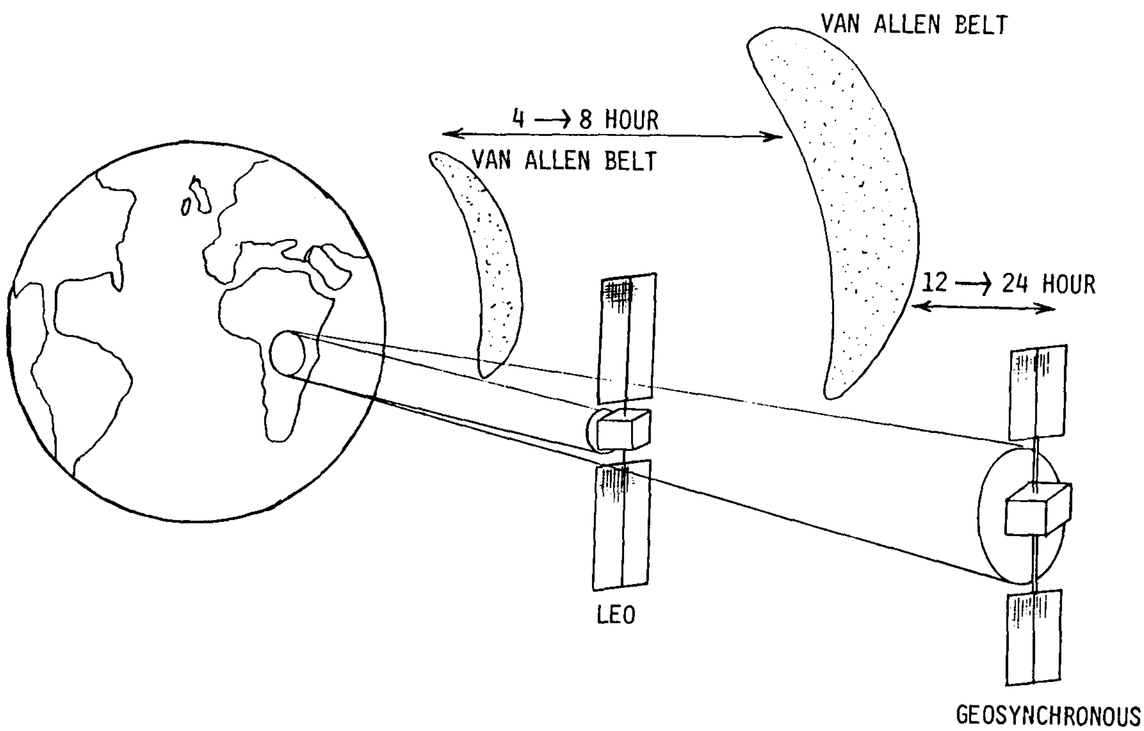
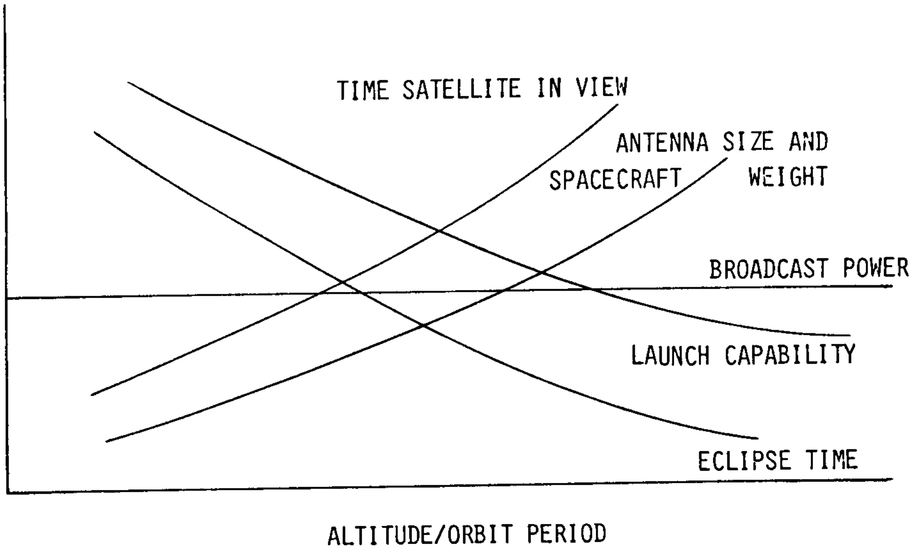


Figure 4. Impact of orbit period.

(FOR CONSTANT AREA COVERAGE)



(FOR CONSTANT SATELLITE ANTENNA SIZE)

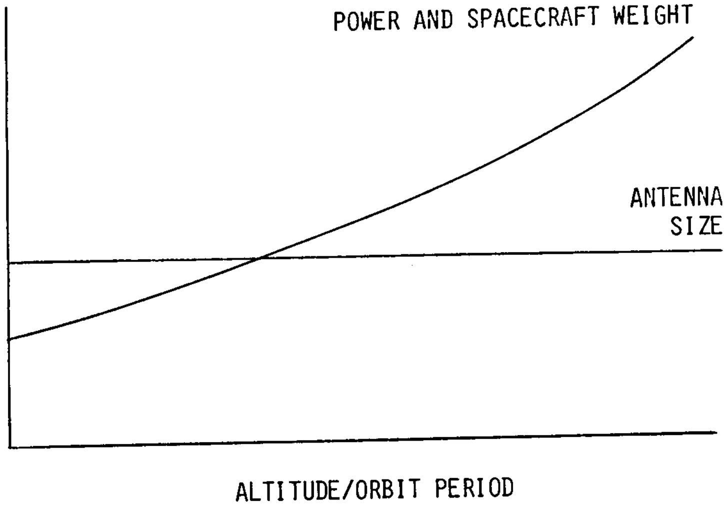


Figure 5. General trade-off trends.

Figure 6 below depicts the required antenna aperture sizes for constant area coverage as a function of orbit altitude. In practice, apertures used by LEO satellites are larger than those indicated to compensate for beam spreading as the beams are steered away from the sub-satellite point.

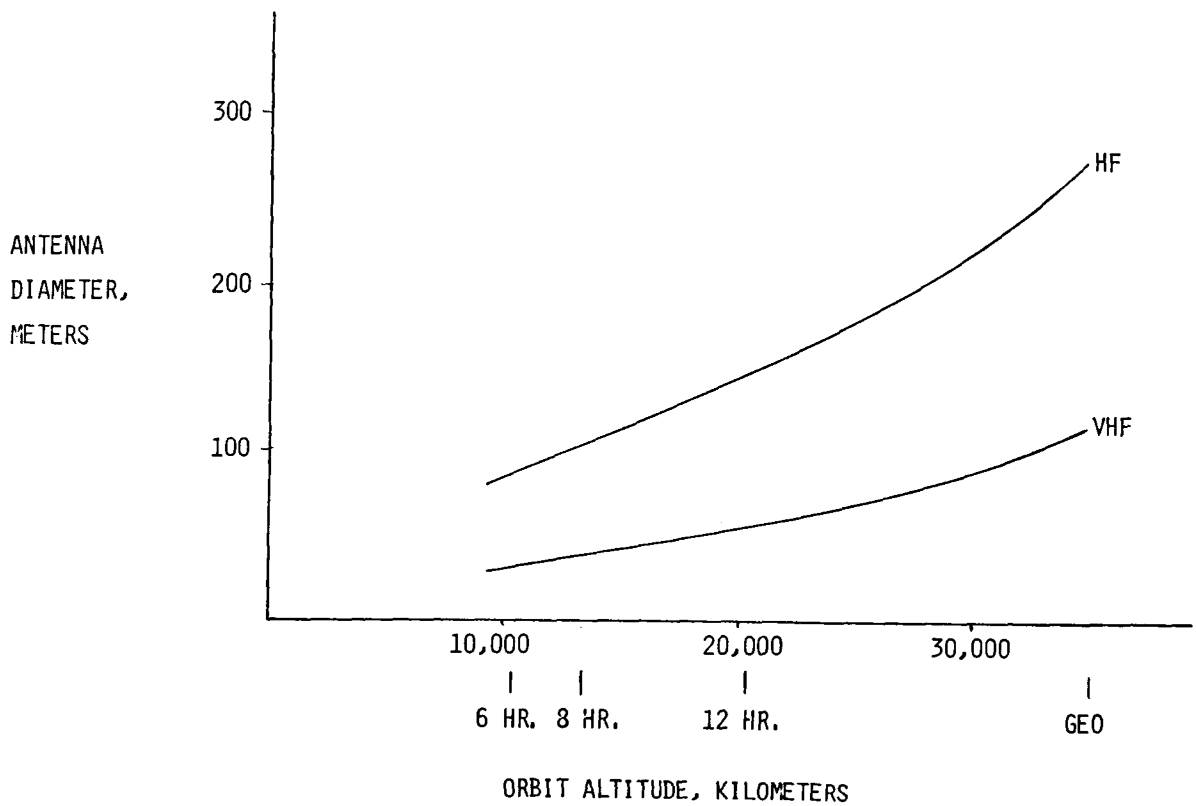


Figure 6. Antenna diameter versus altitude equivalent 3^{o} beamwidth.

Figures 7 through 11 depict antenna concepts developed by our contractors, TRW and Martin Marietta. The TRW LEO concept (figs. 7 and 8) uses high gain (10 - 11 dB) elements in a square phased array to reduce overall aperture size. The TRW GEO concept (fig. 9) uses their cable-catenary antenna. The Martin Marietta LEO concept (figs. 10 and 11) is based on the box truss ring structure. A variable aperture approach is used to illuminate various target broadcast zones differing in apparent size at the satellite. This approach requires transmitters to operate at various power levels as the effective aperture is changed.

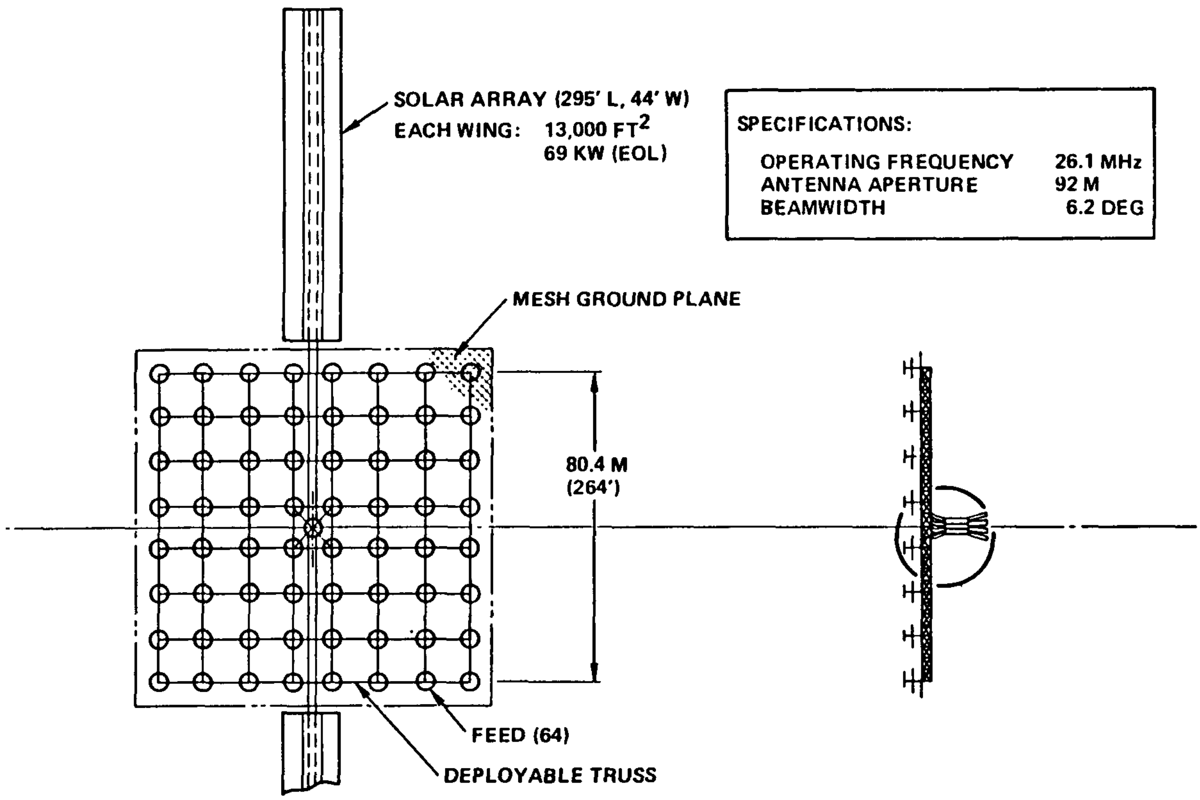


Figure 7. Satellite concept for 8-hr orbit.

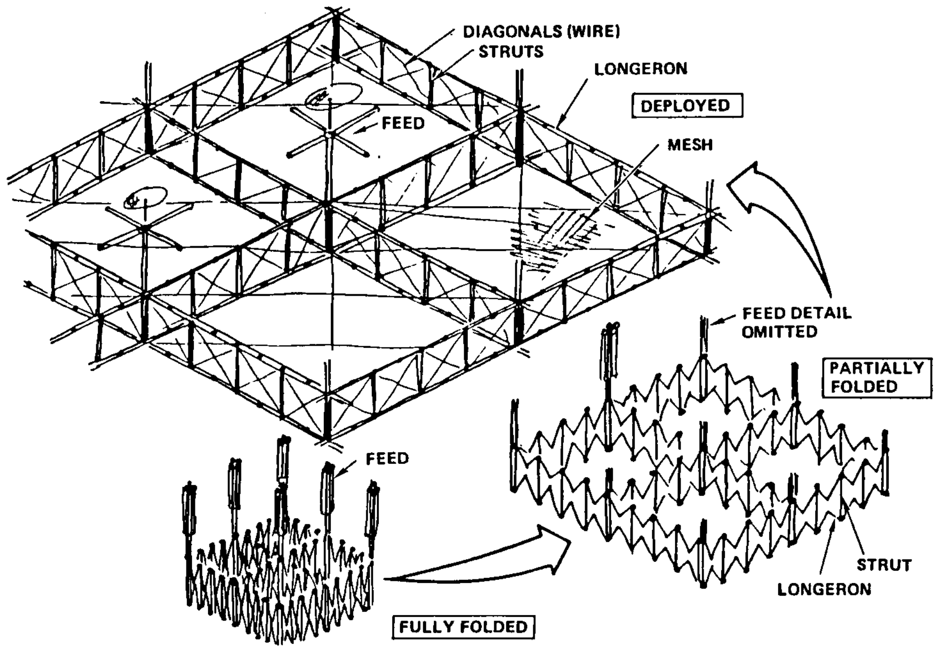


Figure 8. Cross-beam structure stowage and deployment.

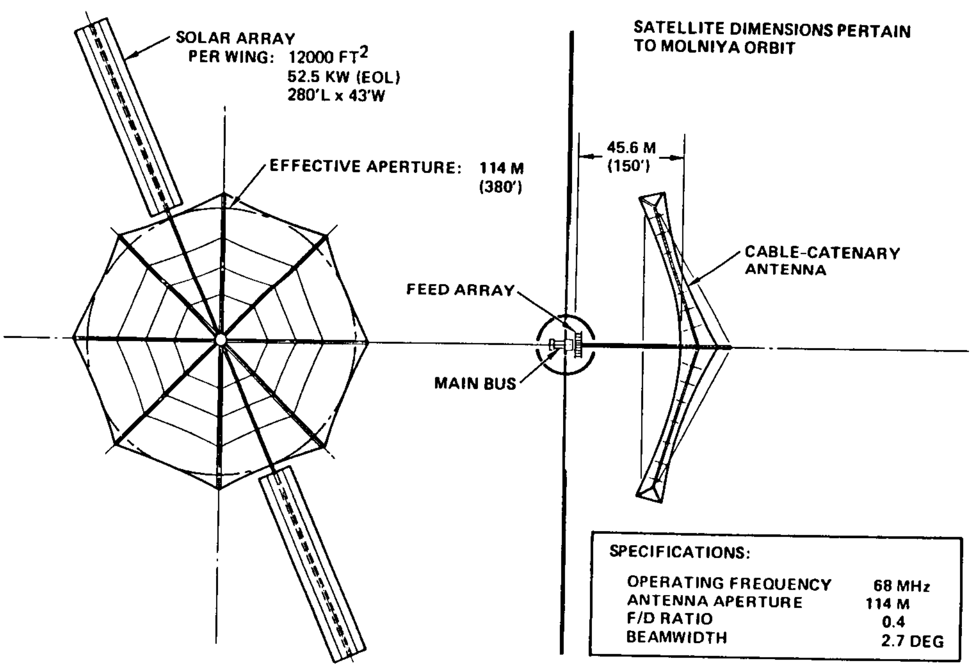


Figure 9. Satellite concept for Molniya and geostationary orbits.

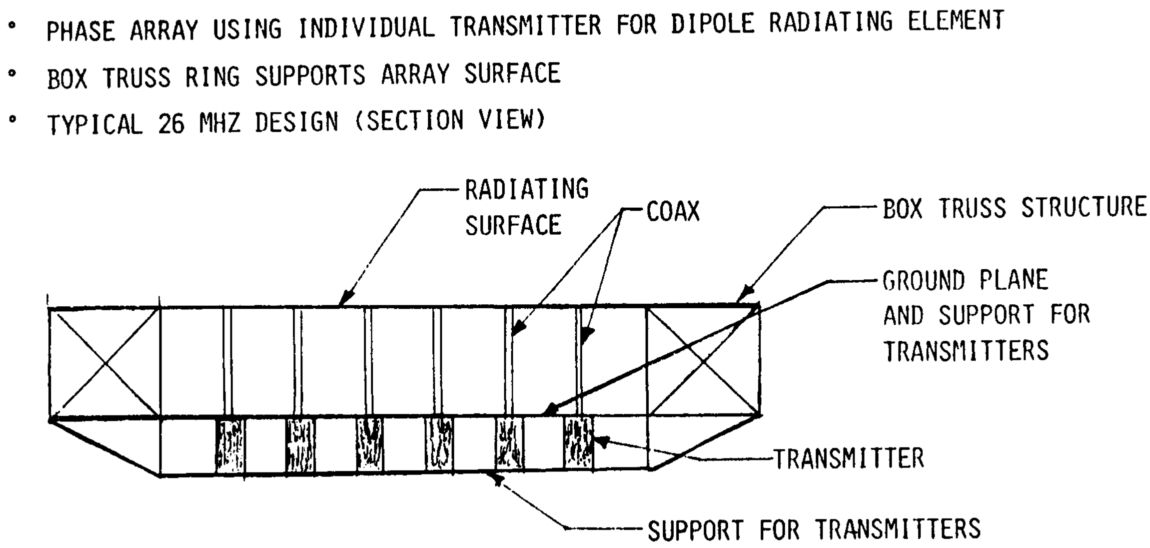


Figure 10. LEO antenna concept.

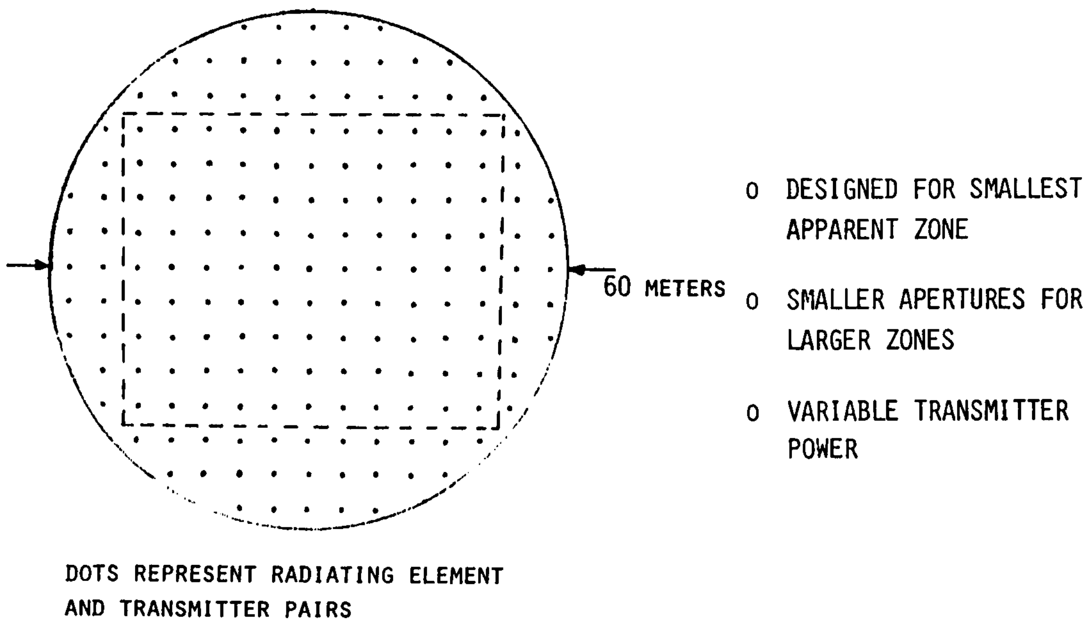
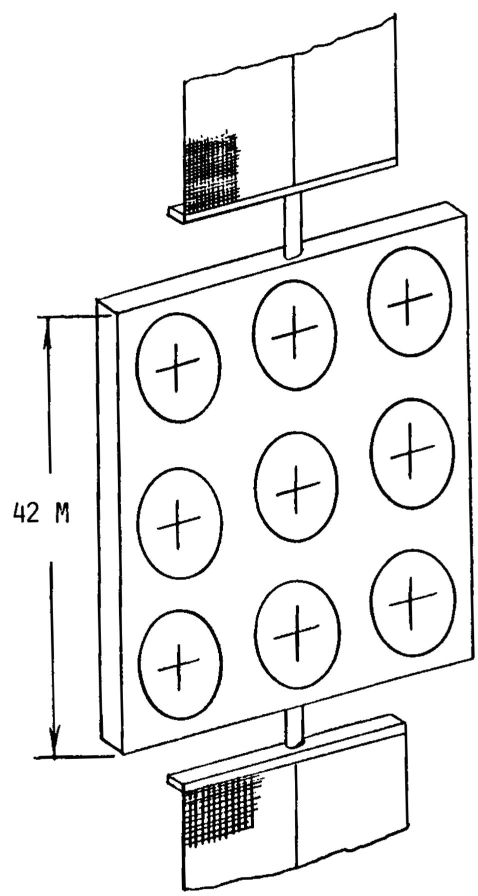


Figure 11. Variable aperture approach.

Obviously, the satellite concepts present technology challenges, particularly in the areas of power generation, handling and distribution, antenna system size, RF power handling, and electric and physical control. At LEO, a particular concern is high-power-plasma interaction.

Most HF and VHF configurations studied to date have been quite large and expensive, consuming full Shuttle-Centaur capability. An HF concept closer to current state of the art is depicted in figure 12. Such a satellite would provide limited service at very low signal strength--but may be an appropriate first-generation concept.

Finally, note that the concepts--as technically intriguing as they are--are only part of a data base. That data base will be used along with other technical, economic, political, and regulatory information to address the broader issue of whether, in fact, satellites offer the USIA a cost-effective means of meeting their mission needs.



- o 10 KW SOLAR ARRAY
- o 9-ELEMENT PHASED ARRAY
- o 650 W TRANSMITTERS
- o 16^{o} BEAMWIDTH
- o 50 - 70 V/m
- o 8-HOUR ORBIT

Figure 12. Low-capability first-generation system.