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BSS SYSTEMS FOR THE 40.5-42.5 GHz BAND

(Question ITU-R 220/11)

(1997)

1 Introduction

The purpose of this Report is to provide a preliminary assessment of the technical feasibility of using the band 40.5 to 42.5 GHz for applications within the broadcasting satellite service (BSS), to which this band is allocated on a worldwide primary basis. Such an assessment is needed because it is commonly assumed that the relatively high propagation losses associated with this band make it more suitable for short-range terrestrial applications than for BSS (see Report ITU-R BT.961). In Europe, European Radiocommunications Committee (ERC) decision, ERC/DEC/(96), 5 June 1996 identifies the 40.5-42.5 GHz band as the harmonized band for multipoint video distribution service (MVDS)*. Moreover, the assumption that the 40.5-42.5 GHz band is not suitable for the BSS has led others to propose that the companion feeder-link band 47.2-49.2 GHz (see Footnote 901 to the international allocation Table) be used for telecommunication services by means of stratospheric balloons and for uplinks to a global non-geostationary satellite orbit (non-GSO) FSS system.

Therefore, another purpose of this Report is to provide examples of technically feasible 41 GHz BSS downlink and 48 GHz feeder-link parameters for use in analyses of frequency sharing between these links and those of MVDS, stratospheric balloon systems, and other proposed non-BSS and non-feeder link applications.

The Report is organized as follows: Section 2 discusses the overall market for satellite broadcasting services and the particular applications for which the EHF frequencies might be suited. Section 3 identifies the existing allocations to the BSS and some of their characteristics. Section 4 then deals with various aspects of the technical feasibility of BSS systems at 40 GHz, including the availability of the necessary hardware components, examples of link budgets, and the expected levels of link signal availability. Section 5 concludes with suggestions for further work, including some specific frequency sharing studies.

2 Demand for BSS services

The demand for satellite broadcasting services has grown exponentially during the past decade. The number of households now receiving television programming directly from satellites is on the order of 40 million, located primarily in Western Europe, Japan, and the United States of America. Except in Japan, early growth was largely dependent on the use of satellites designed for the fixed-satellite service (FSS) with downlinks at 11 GHz in Europe and 4 GHz in the United States of America. As elaborated in the next section, however, most current and near-future growth is taking place in the planned BSS bands near 12 GHz, and can be expected to include markets in the developing countries of Asia, Latin America, and Africa, as well as further penetration in Europe, the United States of America, Japan, and Australia. In nearly all of these systems, the satellite coverage areas are national or multi-national in extent.

The national and multinational coverage of present and near-future BSS systems might not efficiently accommodate the need for more localized coverage. There remains a broad requirement for services more specifically targeted to common interest groups and localities. These services will address the unique national, cultural, educational, and local programming interests of the particular group or locality. In many cases, these services will also need to accommodate strict national and cultural boundary restrictions or, perhaps, just be limited to the specific interests of a particular locality, e.g., a metropolitan area. “Distance learning” is another rapidly growing service that demands more capacity and better distribution to the end user. Already, instructional television networks (via terrestrial microwave and satellites) are being used to provide educational solutions at the university level.

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* The service is similar to the local multipoint distribution service (LMDS) in the United States of America, for which a domestic allocation near 28 GHz has been established.

To fully realize the objectives of serving a multitude of localized areas (communities), it is highly desirable that systems operate in the higher frequency bands, i.e., at 30/20 GHz band and above. Although technically possible at the lower frequency bands, use of these higher frequencies provides additional spectrum capacity to accommodate the capacity projections of the future. It also enables the use of the high-gain highly directive satellite antenna configurations necessary to achieve local area coverage within a more reasonable physical size simplifying satellite antenna design and deployment. As used here, “local area coverage” is taken to be that roughly necessary to cover a major metropolitan area, or an equivalent antenna pattern “footprint” on the earth about 150 to 300 km in diameter. The physical size of the user terminal antennas can also be commensurately smaller, i.e., on the order of 0.5 m or less.

3 BSS frequency allocations

Frequency allocations to the BSS exist in bands near 2, 12, 20, 40, and 85 GHz. Except for the 40 and 85 GHz allocations, which each offer 2 000 MHz of spectrum in all three ITU-R Regions, the width of the bands and their exact location in the spectrum vary from Region to Region. At present, only the bands near 12 GHz (11.7-12.5 GHz in Region 1, 12.2-12.7 GHz in Region 2, and 11.7-12.2 GHz in Region 3) are used to any great extent, and that use is governed by the frequency assignment plans and associated provisions of Appendix 30 of the Radio Regulations (RR).

Although the number of operating 12 GHz BSS systems is still comparatively small, proposed and planned use is very heavy. Over 175 BSS networks have been proposed by some twenty administrations and two international organizations for implementation as modifications to the BSS Plan for Regions 1 and 3. Meanwhile, preparations are under way to revise the existing Regions 1 and 3 Plan at WRC-97 by using “new parameters” for unimplemented assignments and for additional assignments to accommodate “new countries”.

The BSS allocations at 2 GHz and 20 GHz are respectively unsuited or currently unavailable for individual reception TV systems. The BSS allocations near 2 GHz are earmarked either for digital sound broadcasting or for community reception TV. The allocations near 20 GHz (21.4 to 22 GHz in Regions 1 and 3, and 17.3 to 17.8 GHz in Region 2) were added at WRC-92 and were intended for wide-band HDTV. They do not take effect until 1 April 2007.

In contrast, no satellite systems have yet been proposed for the BSS allocations in the 40 and 85 GHz bands (40.5-42.5 GHz and 84-86 GHz). The use of these higher frequencies for local-area coverage BSS systems is, however, worthy of consideration. Although the balance of this Report focuses on the 40 GHz band, many of the same considerations are applicable to the 85 GHz band as well.

4 Technical feasibility of a 40-GHz BSS system

4.1 Overall system considerations

In this section, it will be argued that the 40 GHz BSS allocation and the companion feeder-link band at 47.2-49.2 GHz permit the design of systems that can provide local area programming. Such a system, implemented with a multiplicity of highly directive satellite antenna beams, also permits a very high degree of frequency reuse and the potential for very large numbers of channels-easing frequency congestion problems. Enabling technology developed for existing EHF FSS systems, and the various current BSS systems will facilitate the design of future systems for the 40.5-42.5 GHz band. Expected technological developments from future 30/20 GHz and higher frequency band systems will also facilitate future BSS systems.

Expected data compression advances will make it possible to provide a large number of good-to-excellent quality digital video channels with relatively low data rates of less than 1 Mbit/s a considerable reduction from the 4 to 6 Mbit/s currently employed by the broadcast quality channels of direct-to-home (DTH) systems in the United States of America, Latin America, Japan, and Europe. For distance-learning applications, it is expected that the video requirements can be even lower assuming a classical traditional approach where the instructor does the presentation of material. Thus, it is expected that most teaching can be achieved with approximately 400 kbit/s (or even less, depending on compression gains.)

Current BSS systems use transponders with a bandwidth of 24-27 MHz (depending on Region) with corresponding maximum transponder capacities of 24-27 Mbit/s of compressed video. Using the same modulation techniques and the same forward error correction schemes, but with expected improved compression performance, 60 or more video channels of 400 kbit/s could be transmitted within the current transponder bandwidths.

Higher quality performance will probably be required for local programming and other special applications, but a video channel of 1 Mbit/s should be more than adequate, still allowing 20-25 high quality video channels to be transmitted within the equivalent transponder bandwidths. Of course, there is no reason to retain these current bandwidths for a new system. Definition of appropriate transponder bandwidths will be subject to transponder power-bandwidth trade-offs, together with an assessment of the desirable video channel data rates and number of video channels per transponder.

Future systems could provide a very large number of video channels by employing standard spectrum reuse techniques. For example, a satellite with a 64-element multi-beam antenna could provide up to 19,200 video channels, with 300 channels per beam, where each video channel is 400 kbit/s, and each beam operates with 125 MHz bandwidth at one of two orthogonal polarizations. Lower or higher capacities could be achieved by using the same concept, but with a lower or higher number of beams or a greater or smaller amount of spectrum.

4.2 Representative link budgets

Preliminary link budget calculations show the feasibility of a geostationary system with practical components. For example, assuming an antenna footprint of 0.3° (200 km coverage area) and an 0.5 m user antenna, a 1-Mbit/s channel will require about 1 W of satellite transmitter power to provide adequate (greater than 96%) link availability for the applications considered.

Further, assuming a transponder capacity of 20 to 25 1-Mbit/s video channels, the required transponder power would be about 20 to 25 W (40 to 50 W allowing for an operating back-off of 3 dB) with a corresponding bandwidth of 40-100 MHz, depending on modulation, coding, guardbands, etc. The 0.3° footprint implies 200 beams to fully cover the contiguous United States of America with a resulting total power of 10 kW if all beams were fully loaded. Full use of dual orthogonal polarization in each beam could increase this to 20 kW but probably would not be needed. Alternatively, the satellite transmitter power per carrier could be reduced to a 0.5 W, essentially reducing the payload power requirements by a factor of two, with only a small reduction in link availability. All of these parameters are well within the near-term projected state-of-the-art for satellite communication systems.

Representative link budgets for both clear weather and moderate rain are shown for 40 GHz BSS links in Table 1 and for 47 GHz feeder links in Table 2. As indicated by the parameters used for the rain condition in Table 2, the feeder link can easily be made sufficiently strong to make its contribution to link availability and turn-around noise negligible. The comparatively small number, fairly flexible siting requirements, and highly directive antenna beams of the feeder link earth stations should also negate their interference potential.

4.3 Multi-beam satellite antennas

The use of multi-beam satellite-antenna technologies with small footprints and high transmitter powers (either travelling wave tube amplifiers (TWTAs) or solid-state active-aperture designs could be considered) provide high e.i.r.p. levels allowing the use of small low-cost ground receivers. These small terminals, together with advances in digital compression technology such as MPEG-4, make it possible to design economical satellite-based systems with large numbers of video channels that can be used for distance learning applications or for home reception operating in 40.5-42.5 GHz BSS band.

Multiple spot beams provide an excellent solution to distance learning communication needs (point to multi-point, and multi-point to multi-point). Multiple spot beams are likewise an excellent solution for augmenting current BSS systems with national/cultural unique or local programming . This important enabling technology is being used by an existing government FSS system, which operates at 44 GHz. This system has several fast-hopping multi-beam antennas which provide coverage of the earth viewed from a geosynchronous location. Although, such beams are used for the uplinks in the system, the adaptation for use on BSS downlinks is not expected to be a technological barrier.

TABLE 1

Representative broadcast downlink budget
40.5-42.5 GHz

	Clear weather	Rain
Frequency (GHz)	41.5	41.5
Elevation angle (degrees)	30	30
Transmitter power (linear) (W)	1	1
Transmitting antenna aperture (m)	1.8	1.8
Transmitting antenna beamwidth (degrees)	0.30	0.30
Transmitting antenna gain (EOC) (dBi)	51.8	51.8
Transmitting losses (circuit and pointing) (dB)	4.9	4.9
e.i.r.p. (dBW)	46.9	46.9
Path length (km)	36 780	36 780
Path loss (dB) for 30° elevation	216.5	216.5
Atmospheric loss (clear/rain) (dB)	2.0	6.0
Receiving antenna aperture (m)	0.5	0.5
Receiving antenna beamwidth (degrees)	1.1	1.1
Receiving antenna gain (dBi)	44.1	44.1
Feeder losses (circuit, EOC pointing, polarization) (dB)	3.0	3.0
Receiver noise figure (dB)	3.0	3.0
Receive G/T (dB(K^{-1}))	14.6	13.9
Received carrier-to-noise density (dB · Hz)	71.6	66.9
Data rate (Mbit/s)	1.024	1.024
Required effective E_b/N_0 @ 10^{-5} (dB)	6.0	6.0
Margin (dB)	5.5	0.8

TABLE 2

Representative feeder link budget
47.2 GHz-49.2 GHz

	Clear weather	Rain
Frequency (GHz)	48.2	48.2
Elevation angle (degrees)	55	55
Transmitter power (linear) (W)	2	50
Transmitting antenna aperture (m)	2.0	2.0
Transmitting antenna beamwidth (degrees)	0.23	0.23
Transmitting antenna gain (dBi)	57.5	57.5
Transmitting losses (circuit and pointing) (dB)	2.5	2.5
e.i.r.p. (dBW)	58.0	72.0
Path length (km)	36 780	36 780
Path loss (dB) for 50° elevation	217.4	217.4
Atmospheric loss (clear/rain) (dB)	1.2	25
Receiving antenna aperture (m)	1.5	1.5
Receiving antenna beamwidth (degrees)	0.3	0.3
Receiving antenna gain (EOC) (dBi)	51.8	51.8
Feeder losses (circuit, EOC pointing, polarization) (dB)	5.9	5.9
Receiver noise figure (dB)	3.0	3.0
Receive G/T (dB(K^{-1}))	18.3	18.3
Received carrier-to-noise density (dB · Hz)	86.3	77.0
Data rate (Mbit/s)	1.024	1.024
Required effective E_b/N_0 @ 10^{-5} (dB)	6.0	6.0
Margin (dB)	20.1	10.9

Other systems such as NASA’s ACTS have demonstrated multi-beam antenna technologies operating at 30/20 GHz band and many proposed FSS systems in the 30/20 GHz also use multi-beam antennas. A number of programs are also under way in industry to develop direct-radiating active-aperture phased arrays as an alternate technique for generating a large number of antenna beams. Therefore, no significant technological barriers for satellite antennas operating at 40.5-42.5 GHz and capable of generating the required large number of multiple beams are foreseen.

4.4 Earth station receivers

The availability of both DVB and DSS compliant chips make the design of the ground receivers a very low-cost and readily available commodity, with the front-end RF hardware being the only new development. However, technological advances used in low-noise front-end receivers operating at 44 GHz are currently available and are being used in current satellite system development programs. Even though such hardware has been used primarily for satellite receivers, similar processes can easily be adapted for earth station receivers operating in the 40.5-42.5 GHz band.

4.5 Satellite power amplifiers

Although no specific devices are currently available, the development of high-power TWTAs operating in the 40.5-42.5 GHz band is not expected to be a technological barrier. The lack of devices is simply a reflection that no systems have been operated with similar characteristics. Also, as mentioned above, active-aperture transmitting arrays are under development in industry at virtually all frequency bands from 3-60 GHz. These designs are particularly attractive for the flexible generation of high-power simultaneous multiple beams.

4.6 Satellite buses

Finally, industry commitments to develop high-capacity and high-power satellite buses make it possible to plan for feasible future systems that can make efficient and flexible use of the available frequency spectrum. These bus designs incorporate several technological advancements and have projected capabilities to generate more than 15 kW of electrical power and accommodate payload weights of up to 1000 kg.

4.7 Link availability

It should be noted that systems operating in the 40.5-42.5 GHz BSS band will need to be offered at somewhat lower link availabilities than traditional systems, which operate at FSS or even current BSS bands. The detrimental atmospheric effects (with rain being the most severe) preclude the design of practical satellite systems that can operate with the traditional high system availabilities (greater than 99.5%). Link margins necessary to support such high availabilities in regions with moderate or high rain rates can easily be more than 20 dB.

Requiring such high margins to protect against rather rare events (even in high rain regions) does not result in practical or economic system designs and would greatly impede the development of otherwise very useful public services. However, practical and operationally useful services are feasible at somewhat lower, but still perfectly acceptable, availabilities (96% to 99%) almost everywhere. Table 3 shows the estimated link availability (downlink only) for several selected cities in the contiguous United States of America, assuming the parameters used in Table 1. The applications primarily considered here, i.e., distance learning and local programming, are direct-to-end-user type services and are typically tolerant of the somewhat more frequent occurrences of outages. Also, these systems often lend themselves to system level solutions when rain outages do occur.

Recent test data collected from the ACTS satellite, and older data from INTELSAT and Olympus systems, have made it possible to refine the ability to understand and predict the atmospheric effects. Frequency scaling of the 30/20 GHz band rain databases will allow system designers to better understand and predict the effects on systems operating at 40.5-42.5 GHz. The atmospheric effects in the feeder-link band (47.2-49.2 GHz, specified in the RR for the 40.5-42.5 GHz BSS band), are even greater than those for the downlinks. However, feeder links can typically afford the necessary excess margins and are more amenable to additional solutions such as site diversity. Or, a system designer/operator may decide, at a system level, to compromise performance objectives slightly and simply accept operation at the resulting lower availabilities.

TABLE 3

Estimated link availability for some selected cities
40.5-42.5 GHz using link parameters from Tables 1 and 2

City	Annual availability (%)
Boston	98.2
Chicago	98.5
Denver	99.1
Detroit	98.5
Houston	96.8
Kansas City	98.3
Los Angeles	99.4
Miami	96.5
New York	98.1
Seattle	99.2
Tampa	96.6
Washington D.C.	98.0

5 Conclusions

Given the relatively small advancements in technology required to develop systems that can use the 40.5-42.5 GHz BSS band (together with the corresponding feeder-link band at 47.2-49.2 GHz), and the benefits potentially attained from such systems, it is recommended that further study of broadcast satellite service system applications that could operate in this band be conducted.

In addition, since potentially incompatible systems have been proposed for both the 40.5-42.5 GHz and the 47.2-49.2 GHz bands, it is recommended that studies be initiated on an urgent basis to assess the practical feasibility of frequency sharing between the BSS and systems of the proposed types. Specific candidates for such studies are the MVDS systems proposed for the 40.5-42.5 GHz band in Europe, the global stratospheric balloon system proposed for parts of the 47.2-49.2 GHz band, and the global non-GSO FSS systems whose uplinks would occupy all of that band (uplinks at 47.2 to 50.2 GHz and downlinks at 37.5 to 40.5 GHz).