Ka-Band (32 GHz) Allocations for Deep Space

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At the 1979 World Administrative Conference, two new bands were allocated for deep space telecommunications: 31.8–32.3 GHz, space-to-Earth, and 34.2–34.7 GHz, Earth-to-space. These new bands provide opportunity for further development of the Deep Space Network and its support of deep space research.

This article discusses the history of the process by which JPL/NASA developed the rationale, technical background, and statement of requirement for the new bands. Based on this work, United States proposals to the conference included the new bands, and subsequent U.S. and NASA participation in the conference led to successful allocations for deep space telecommunications in the 30 GHz region of the spectrum. A detailed description of the allocations is included in the article.

I. Introduction

Successful deep space telecommunication requires some international and national basis for use of specific frequency bands with provision for sharing with other users, and provision for providing protection of individual channels from interference from other users.

This article presents a brief history of steps that led to the international allocation of new bands for deep space telecommunications in the 30 GHz region of the radio frequency spectrum. Following the historical narrative, a rather detailed description of the allocations is given.

II. The 32/34 GHz Band Allocations for Deep Space Research: How They Were Obtained

In 1977, the United States was preparing for the 1979 World Administrative Radio Conference (WARC). At this conference, the entire radio frequency spectrum and its usage as governed by the Radio Regulations was to be reconsidered. The result of the WARC would be a new treaty, adopted by 150 nations of the International Telecommunication Union (ITU). Such a broad ranging conference is rare, and decisions taken in 1979 would likely affect the use of much of the radio spectrum until the turn of the century.

NASA was a major participant in the U.S. preparations for WARC 79, looking at the need for existing and new radio frequency bands to support the agency's future programs. At that time, JPL studies suggested that an orbiting deep space relay satellite (ODSRS) could be a next step in developing a greater capability for the DSN. The satellite would be in a geostationary orbit, and provide communication links to spacecraft in deep space and to the Earth (Ref. 1).

To protect the precious deep space bands, it was proposed to use other bands for the links between the Earth and the

satellite. For the links between the satellite and deep space, three candidate frequency ranges were identified. A pair of bands near 31 GHz would provide for links to and from deep space, but with the advantage of also permitting links directly with DSN stations on Earth. This possibility arises from the microwave propagation window through the atmosphere near that frequency. The ability to perform a deep space mission from either the ODSRS or the Earth would provide a safer environment for mission communications during development of the satellite capability. A band pair near 95 GHz would also allow a degree of direct communication with earth stations, although development for links at such a high frequency would be far in the future.

Ultimately, the satellite to deep space links would have the best protection from terrestrial radio interference if they were in a part of the spectrum where the atmosphere is relatively opaque. A pair of bands near 60 GHz would provide high atmospheric attenuation and the desired protection.

In mid 1977, it was proposed by JPL[1] that the U.S. should seek deep space allocations for uplink-downlink band pairs near 31, 60, and 95 GHz in support of the future Orbiting Deep Space Relay Satellite (ODSRS). Each band was to have primary status, be 500 MHz wide, and have a specified direction of transmission.

In reply, NASA[2] asked that a description of ODSRS frequency requirements be prepared for use in U.S. WARC deliberations, and that a technical paper be prepared for submission to the Comite' Consultatif International des Radiocommunications (CCIR). That organization was scheduled to hold a Special Preparatory Meeting (SPM) in the fall of 1978 to lay the technical groundwork for the 1979 administrative conference. CCIR is the technical arm of the ITU with regard to radio communications.

In early January 1978, a draft CCIR technical report[3] was sent to the chairman of U.S. CCIR Study Group 2. This group deals with space research and radio astronomy. The paper provided the rationale for the choice of ODSRS frequency bands, and was submitted as an input to the CCIR process of preparing for its SPM in support of the conference.

The CCIR draft report was also forwarded to NASA[4] for its review, but with an additional proposal that six specific bands (three uplink-downlink pairs) be sought by the United States for ODSRS purposes.

A week later, the list of NASA frequency requirements proposed for inclusion in the U.S. submission to the 1979 conference was distributed.[5] The list did not include the bands and status proposed by JPL for ODSRS links. Provision for ODSRS was evidently held by NASA to be insufficient justification for protected deep space links above 20 GHz.

The effort to have technical input to the CCIR failed. The CCIR paper concerning frequencies for ODSRS did not leave the United States. Not having input from the U.S., the CCIR SPM held in October–November 1978 did not deal with the issue of new deep space bands above 20 GHz. Consideration of the matter by the WARC in 1979 would therefore have to rest on U.S. proposals to the conference itself, and not CCIR technical advice coming from the SPM.

During 1978, the U.S. proposals for the WARC became more fully developed, and included the NASA list of requirements, essentially as presented in January.

The situation in February 1979 appeared to be that the then current U.S. proposal for radio frequency allocations foreclosed the option of protected deep space telecommunications links in the 20–120 GHz region, except for a band at 65–66 GHz. Allocations proposed at 31–31.3 GHz and 31.8–32.3 GHz would permit deep space links, but without any protection from interference.

Although it was late, JPL undertook the task of getting the U.S. position changed. It was clear that a stronger rationale than ODSRS alone was needed. A number of steps were taken.

(a) In early February, 1979, five reasons for maintaining the option to operate a ground-based DSN near 30 GHz were stated:

(1) 30 GHz is a candidate technology in the evolution toward increased link performance as needed to enhance or enable future missions;

[1]de Groot, N. F. (JPL letter 339-77-128; internal document), Jet Propulsion Laboratory, Pasadena, California, 13 June 1977.

[2]Eaton, E. L. (NASA letter TN/#1483; internal document), Jet Propulsion Laboratory, Pasadena, California, 25 August 1977.

[3]de Groot, N. F. (JPL letter 3398-78-253; internal document), Jet Propulsion Laboratory, Pasadena, California, 3 January 1978.

[4]Goodwin, P. S. and Bayley, W. H. (JPL letter 420-PSG:mti; internal document), Jet Propulsion Laboratory, Pasadena, California, 11 January 1978.

[5]Associate Administrator for Space Tracking and Data Systems, *NASA Frequency Requirements for the General World Administrative Radio Conference 1979 (WARC 1979)* (NASA letter TN/1607; internal document), Jet Propulsion Laboratory, Pasadena, California, 16 January 1978.

(2) 30 GHz is the next logical step in the evolution of technology development (from 2 to 8 to 30 GHz to submillimeter to optical, rather than an intermediate step at 13 GHz);

(3) 30 GHz is the next logical step in the evolution of deep space allocations from the congested lower frequency bands near 2 and 8 GHz to broader, less congested higher frequency bands;

(4) 30 GHz offers potential sharing of technology developments with other near-Earth NASA sponsors (especially OAST and OSSA); and

(5) 30 GHz is the next logical step in the evolution from a ground-based Deep Space Network (DSN), with a "clear weather" window to back up an ODSRS.

(b) JPL emphasized to NASA[6] its future needs and the likely evolution of technology and the DSN, and asked that NASA reconsider its needs in connection with preparations for the WARC.

(c) The feasibility of incorporating the necessary frequency multipliers and dividers in a spacecraft transponder to operate near 30 GHz was confirmed. The rationale for the new bands was further developed. Advantages to flight projects and radio science were solidified. JPL encouraged NASA support for new deep space bands[7] and informed NASA[8] that a more fully developed analysis of the need for 30 GHz was being documented, along with a recommendation for specific band pairs to be proposed at the WARC.

In mid-May, a lengthy study on the applicability of the 32 GHz frequency region to deep space telecommunications was completed at JPL. The study considered attenuation, noise temperature, wavefront distortion, and related aspects of propagation through space and the atmosphere. Also considered were the effects of antenna surface precision, pointing accuracy, and spacecraft transmitter efficiency. These factors were all treated in a numerical comparison of estimated link performance at 8 GHz and 32 GHz. The potential advantage of 32 GHz deep space links was evident, amounting to an estimated maximum performance increase of 6.8 dB, as compared to 8.4 GHz, assuming 90 percent weather confidence and a 30 degree elevation angle. Subsequent studies have shown even greater increases (Ref. 2).

In early July, an edited version of the JPL position was sent to NASA.[9] A discussion of benefits to radio science was included, along with a list of four candidate band pairs in the 30.9 to 35.1 GHz region. The letter asked that all necessary steps be taken by NASA to secure the needed band allocations. In light of expected resistance, a request for bands near 60 and 100 GHz was not included.

Just eight days later NASA wrote to the U.S. WARC delegation spokesman for the Allocations Committee dealing with the 1215 MHz to 40 GHz frequency range, and asked that the JPL/NASA requirement for new bands near 32 GHz be included in the U.S. proposal to the WARC.[10] The requested change to the U.S. conference proposal was considered and adopted. The formal U.S. position concerning bands for deep space research had been successfully changed, albeit at the last minute.

In final preparation for the conference, JPL advised NASA[11] as to various negotiating trade-offs that might be needed in guiding action by the U.S. delegation at the conference. The WARC began its ten week deliberations in late September 1979. As it turned out, the principal obstacle to the requested deep space allocations was potential non-NASA use of that frequency within the U.S. This problem was resolved by a memorandum of understanding that geographically restricts 32/34 GHz deep space operations within the U.S. to Goldstone, California.

In its new Table of Allocations, the 1979 General WARC included two new bands for deep space research near 30 GHz. The lengthy and sometimes intense activity by JPL and NASA had resulted in new opportunities for deep space exploration, and provided the basis for further evolution of the DSN capability to serve flight projects.

III. The 32/34 GHz Allocations for Deep Space Research: What They Are

Radio frequency usage is based on band allocations by the ITU. A Table of Allocations is a major part of the Radio Regulations (Ref. 3). The Regulations are the expression of an

[6] Bayley, W. H. (JPL letter 410-WHB:baw; internal document), Jet Propulsion Laboratory, Pasadena, California, 6 March 1979.

[7] James, J. N. (JPL letter 910-JNJ:pd; internal document), Jet Propulsion Laboratory, Pasadena, California, 26 March 1979.

[8] de Groot, N. F. (JPL letter 3396-79-057; internal document), Jet Propulsion Laboratory, Pasadena, California, 20 April 1979.

[9] Bayley, W. H., *Applicability of the 32 GHz Frequency Region to Deep Space Communications* (JPL letter 400-WHB:jr; internal document), Jet Propulsion Laboratory, Pasadena, California, 9 July 1979.

[10] Kimball, H. G., *Requirement for Deep Space Communications Allocation in the 32 GHz Region* (NASA letter TN/2498; internal document), Jet Propulsion Laboratory, Pasadena, California, 17 July 1979.

[11] Bayley, W. H. (JPL letter 400-WHB:baw; internal document), Jet Propulsion Laboratory, Pasadena, California, 21 September 1979.

international treaty, ratified by most of the 160 administrations (countries) that are members of the ITU.

Assignment of radio frequencies for particular radio stations is made by national administrations, not by the ITU. These frequency assignments are expected to be in harmony with the Table of Allocations that specifies which radio services may operate in particular bands.

In addition to the international Table of Allocations, each administration has a domestic table, which may impose additional restrictions on frequency assignment within that administration.

The allocations that affect deep space research in the 32 and 34 GHz bands are particularly complex, because of variations included in the international Table and as further constrained by rules in some administrations.

In the tables that follow, radio services shown in upper case have primary status. That is, they enjoy equality with other primary services in resolving interference problems. Secondary allocations, are shown in lower case. These allocations allow operation, but give no protection with respect to primary users. Secondary users may not complain of interference, and must cease operation if they cause interference.

The numbers shown under the service allocations refer to footnotes; except where clearly irrelevant, the text of the listed footnotes is given following the statement of allocation. In a few cases, there are references to footnotes that lead down a path of further references; these paths are not followed here and should not impede appreciation of the material.

A. ITU Band Allocations

The following are ITU band allocations:

Band, GHz	Allocation
31.8–32	RADIONAVIGATION Space Research 890 891 892
32–32.3	INTER-SATELLITE RADIONAVIGATION Space Research 890 891 892 893
34.2–35.2	RADIOLOCATION Space Research 894 895 896

890 Different category of service: in Australia, Spain and the United States, the allocation of the band 31.8–32.3 GHz to the space research service (deep space) in the space-to-Earth direction is on a primary basis (see No. 425). This use shall not impose power flux-density constraints on the inter-satellite service in the band 32–32.3 GHz.

891 Different category of service: in Bulgaria, Cuba, Hungary, Mongolia, Poland, German Democratic Republic, Czechoslovakia, and U.S.S.R., the allocation of the band 31.8–32.3 GHz to the space research service is on a primary basis (see No. 425).

892 Subject to agreement obtained under the procedure set forth in Article 14, the band 31.8–33.8 GHz may also be used in Japan for space-to-Earth transmissions in the fixed-satellite service up to December 31, 1990.

893 In designing systems for the inter-satellite and radionavigation services in the band 32–33 GHz, administrations shall take all necessary measures to prevent harmful interference between these two services, bearing in mind the safety aspects of the radionavigation service (see Recommendation 707).

894 Additional allocation: in Afghanistan, Saudi Arabia, Bahrain, Bangladesh, Egypt, United Arab Emirates, Spain, Finland, Gabon, Guinea, Indonesia, Iran, Iraq, Israel, Kenya, Kuwait, the Lebanon, Libya, Malaysia, Malawi, Mali, Malta, Morocco, Mauritania, Nepal, Niger, Nigeria, Oman, Pakistan, Philippines, Qatar, Syria, Senegal, Singapore, Somalia, Sudan, Sri Lanka, Sweden, Tanzania, Thailand, Togo, Tunisia, Yemen A.R., and Zaire, the band 33.4–36 GHz is also allocated to the fixed and mobile services on a primary basis.

895 Different category of service: in Australia, Spain, and United States, the allocation of the band 34.2–34.7 GHz to the space research (deep space) (Earth-to-space) service is on a primary basis (see No. 425).

896 Different category of service: in Bulgaria, Cuba, Hungary, Poland, Mongolia, German Democratic Republic, Czechoslovakia, and U.S.S.R., the allocation of the band 34.2–35.2 GHz to the space research service is on a primary basis (see No. 425).

No. 425 is a regulatory provision dealing with footnote allocations in particular countries.

Article 14 is a regulatory provision that dictates a procedure for the coordination of frequency assignments by administrations.

B. Band Allocations by the United States

Within the U.S., bands are allocated as listed in Ref. 4. These allocations are necessarily in the context of the ITU Radio Regulations, but impose additional conditions. In some cases, there are separate allocations for government and non-government uses, as indicated below. Where no distinction is given, the allocation applies to both situations.

Band, GHz	Allocation
31.8–32	RADIONAVIGATION US69 US211 US262
32–32.3	RADIONAVIGATION INTER-SATELLITE US69 US262 US278 893
33.4–36.0	RADIOLOCATION (government) Radiolocation (non-government) US110 US252 897 G34

US69 In the band 31.8–33.4 GHz, ground-based radionavigation aids are not permitted except where they operate in co-operation with airborne or shipborne radionavigation devices.

US110 In the frequency bands ... and 33.4–36 GHz, the non-Government radiolocation service shall be secondary to the Government radiolocation service....

US211 In the bands ... 31.8–32 GHz ... applicants for airborne or space station assignments are urged to take all practicable steps to protect radio astronomy observations in the adjacent bands from harmful interference; however, US74 applies.

US252 The bands ... 34.2–34.7 GHz are also allocated for earth-to-space transmissions in the Space Research Service, limited to deep space communications at Goldstone, California.

US262 The band 31.8–32.2 GHz is also allocated for space-to-earth transmissions in the Space Research Service, limited to deep space communications at Goldstone, California.

US278 In the ... and 32–33 GHz bands, nongeostationary intersatellite links may operate on a secondary basis to geostationary satellite links.

G34 In the band 34.4–34.5 GHz, weather radars on board meteorological satellites for cloud detection are authorized to operate on the basis of equality with military radiolocation devices. All other non-military radiolocation in the band 33.4–36 GHz shall be secondary to the military services.

893 See ITU footnotes.

897 This ITU footnote does not apply to the deep space portion of the U.S. 33.4–36 GHz allocation.

C. Band Allocations by Australia

Band allocations for Australian users are given in Ref. 5.

Band, GHz	Allocation
31.8–32	RADIONAVIGATION SPACE RESEARCH (deep space) (space-to-Earth) Space research
32–32.3	INTER-SATELLITE RADIONAVIGATION SPACE RESEARCH (deep space) (space-to-Earth) AUS45 Space research
34.2–34.7	RADIOLOCATION AUS11 SPACE RESEARCH (deep space) (Earth-to-space) Space research

AUS11 Assignments to users other than the Department of Defense will not normally be authorized for this service.

AUS45 The space research (deep space) service in the space-to-Earth direction shall not impose power flux density constraints on the inner-satellite service in the band 32–32.3 GHz.

D. Allocations by Spain

Deep Space allocations by the Spanish administration are essentially those of the ITU Table of Allocations.

References

1. Hunter, J. A., *Orbiting Deep Space Relay Station Study Final Report*, Jet Propulsion Laboratory Publication 79-30, Jet Propulsion Laboratory, Pasadena, California, June 15, 1979.

2. Koerner, M. A., "Relative Performance of X-band and 32 GHz Telemetry Links on the Basis of Total Data Return Per Pass," *TDA Progress Report 42-87*, Jet Propulsion Laboratory, Pasadena, California, pp. 65-80, November–December 1986.

3. *Radio Regulations*, International Telecommunication Union, Geneva, 1982, Revised 1985.

4. *Manual of Regulations and Procedures for Federal Radio Frequency Management*, National Telecommunications and Information Administration, United States Department of Commerce, Washington, DC, 1985.

5. *Australian Table of Frequency Allocations*, Department of Communications, Australian Government Publishing Service, Canberra, Australia, 1982.