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WARC 92 AND SOME THOUGHTS AS TO ITS IMPACT ON THE NASA PROPAGATION PROGRAM

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Abstract - The World Administrative Radio Conference of 1992 (WARC 92) was held in Torremolinos, Spain, Feb. 3 - March 3, 1992. Major topics considered included Shortwave Broadcasting, Mobile and Mobile-Satellite Service, Broadcasting Satellite Service (Sound and HDTV), Space Services above 20 GHz, and Space Research. Considerable attention was give to the congested 1-3 GHz band in general and to Low Earth Orbit (LEO) Mobile-Satellite Service, including "little" LEO's operating below 1 GHz and to "big" LEO's operating above 1 GHz. Significant new allocations were made for generic Mobile-Satellite Services (MSS). Proposals for allocations for uplink Power Control Beacons and for Space Research received favorable treatment.

1. Mobile-Satellite Service (MSS)

The United States introduced proposals to replace specific allocations for aeronautical, maritime, and land mobile service at L band with generic MSS allocations. There was support for making new mobile-satellite allocations generic but opposition to modifying the existing allocations. A number of new allocations for for MSS were made, including four Primary pairs for uplinks and downlinks operating at frequencies between 1,610 MHz and 2,690 MHz (Table 1). The total bandwidth added for MSS by these four pairs of links was 153 MHz. In addition the Secondary pair of 1,930-1,970 MHz (Uplink) and 2,120-2,160 MHz (Downlink) provide an additional 80 MHz, and the allocations not listed in pairs add 99.9 MHz. Saudia Arabia, Mexico, and others managed to have implememtation, of the last pair of new Primary allocations for MSS (No. 4), postponed until 2005, but the U.S. takes issue with this postponement. Coordination under a Resolution COM 5/8 is called for in the case of many of the MSS allocations. See Section 4 for mention of MSS near 20 GHz and 30 GHz.

In addition to the new allocations mentioned above for MSS, the entire 1700 to 2690 MHz band was upgraded to Primary Worldwide for Mobile Service . Although the U.S. considered it was premature to make allocations for Future Public Land Mobile Telecommunication Systems (FPLMTS), WARC 92 did make some allocations for FPLMTS, as sub-bands of the MSS band, to have something on record for it (Table 2). The FPLMTS will consist of both satellite and terrestrial parts (Spectrum, 1992). Some allocations were made for terrestrial service alone and the bands 2,010 - 2,025 MHz and 2,185 - 2,200 MHz were allocated for both terrestrial and satellite service. It is considered that FPLMTS will not be limited in the future to the bands allocated for it by WARC 92. Also shown on Table 2 are allocations for Aeronautical Public Correspondence (APC). The U.S. received its requested allocation for APC by a footnote applying to Canada, Mexico, and Argentina as well, but the Worldwide Primary allocation was for higher frequencies.

2. LEO Mobile-Satellite Service

Much attention at WARC 92 was given to Low-Earth-Orbit (LEO) systems. LEO technology has been considered to be an area of technical leadership by the U.S., but before the WARC there were no international spectrum allocations available for LEO systems. Significant allocations for both geostationary (GEO) and low-Earth-orbit (LEO) systems were included in U.S. proposals to the 1992 WARC, and obtaining such allocations was among the highest U.S.

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Table 1. PRIMARY MOBILE-SATELLITE SERVICE ALLOCATIONS, WARC'92

WARC '92

PRIMARY MOBILE-SATELLITE SERVICE ALLOCATIONS

1492 - 1525 MHz	Region 2	(33 MHz)
1525 - 1530 MHz	Regions 2 and 3	(5 MHz)
1530 - 1544 MHz	Primary by footnote in U.S. etc., Priority to MMS	(14 MHz)
1555 - 1559 MHz	Primary by footnote in U.S. etc., Priority to AMS	(4 MHz)
1626.5 - 1631.5 MHz	Regions 2 and 3, Priority to MMS	(5 MHz)
1656.6 - 1660.5 MHz	Primary by footnote in U.S. etc., Priority to AMS	(3.9 MHz)
1675 - 1710 MHz	Region 2, Uplink, LEO	(35 MHz)

Primary Listing by Uplink, Downlink Pairs

1.	1610 - 1626.5 MHz	(16.5 MHz, LEO)
	2483.5 - 2500 MHz	(16.5 MHz, LEO, GEO)
2.	1970 - 1980 MHz	(10 MHz, LEO, GEO)
	2160 - 2170 MHz	(10 MHz, LEO, GEO, Region 2)
3.	1980 - 2010 MHz	(30 MHz, LEO, GEO)
	2170 - 2200 MHz	(30 MHz, LEO, GEO)
4.	2500 - 2520 MHz	(20 MHz, LEO, GEO, Downlink, 2005)
	2670 - 2690 MHz	(20 MHz, LEO, Uplink, 2005)

Table 2. ALLOCATIONS FOR FPLMTS AND APC

WARC '92 Comparison Matrix	
Mobile Services including Future Public Land Mobile Telecommunication System and Aeronautical Public Correspondence	
U.S. Proposal	**WARC '92 Decision**
Mobile Services	
No Proposal	1700 - 2690 MHz Upgraded to Primary Worldwide
Future Public Land Mobile Telecommunication System *	
No Proposal - premature to designate a band(s)	1885 - 2010 MHz ** Terrestrial Only
	2010 - 2025 MHz *** Terrestrial & Satellite
	2110 - 2185 MHz ** Terrestrial Only
	2185 - 2200 MHz *** Terrestrial & Satellite
Aeronautical Public Correspondence *	
849 - 851 MHz (Ground to Air) 894 - 896 MHz (Air to Ground)	849 - 851 MHz (Ground to Air) 894 - 896 MHz (Air to Ground) Country Footnote for U.S., Argentina, Mexico and Canada (Primary)
	1670 - 1675 MHz (Ground to Air) 1800 - 1805 MHz (Air to Ground) Worldwide Primary

* *Note:* The bands listed for FPLMTS and APC are intended for use by these applications and do not preclude the use of different bands.

** *Note:* Terrestrial implementation by 1 January 2000.

*** *Note:* Satellite implementation by 1 January 2010.

priorities at the WARC. A separate heading is used here for LEO systems, to draw attention to them, but both GEO and LEO mobile systems fall into the category of MSS and are able to use allocations mentioned in the previous section for MSS.

Prior to the WARC, U.S. Ambassadors to all CEPT countries, Canada, and Japan were asked to make high-level contacts about LEO allocations. [There are 32 CEPT (Conference of European Postal and Telecommunications Administration) countries.] Detailed briefings were also given at the WARC by the U.S. companies that had formulated proposals for LEO service. Heads of delegations were invited to social events, and the U.S. Ambassador to Spain, Joseph Zappala, made a special visit to WARC to underline the importance of LEO's. The LEO systems can be divided into two categories, little LEO's, low cost, low-data-rate systems operating below 1 GHz, and big LEO's, systems operating at frequencies above 1 GHz and providing greater capacity and variety of services, including worldwide services in personal communications to handheld terminals. It is reported that the efforts to obtain allocations for LEO's, carried out against considerable resistance, were successful for the U.S.

The February, 1992 issue of *Spectrum* (1992) listed the following little LEO systems: Leosat (Leosat, Inc., Ouray, CO), Orbcomm (Orbital Communications Corp., Fairfax, VA), Starnet (Starsys Inc., Washington, DC),, and VITASAT [Volunteers in Technical Assistance (VITA), Arlington, VA]. VITA has been involved since the early 1980's with LEO's and was a party in developing a store-and-forward technique which, rather than providing real-time service, would utilize a satellite orbit which would bring a satellite into view of all points on Earth every 12 hours. Such a system could be used for electronic mail (Satellite Communications, 1992; Ward, 1991). The following big LEO systems were listed: Aries (Constellation Communications Inc., Herndon, VA), Ellipso, (Ellipsat, Washington, DC), Globalstar (Loral Cellular Systems Corp, New York, NY). Iridium (Motorola, Chandler, AZ), and Odyssey (TRW Inc. Redondo Beach, CA). It is now Loral Qualcomm Satellite Services, Inc. that is responsible for Globalstar.

The best known LEO system is Motorola's Iridium (Grubb, 1991), a big LEO system, named because its planned 77 satellites, circulating at a height of 778 km (420 Miles) in polar orbits around the Earth, are reminiscent of the 77 electrons circulating around an iridium nucleus. The satellites will be in seven planes containing 11 satellites each, the planes equally separated in longitude. The orbital period of each satellite will be about 100 minutes. A user will never have to communicate more than 2,315 km to reach a satellite. Higher frequencies of 27.5 - 30 GHz and 18.8 - 20.2 GHz are to be used for links to and from base stations, and frequencies of 22.5 - 23.5 GHz will be used for links between satellites, according to plans. Motorola was very well represented at the WARC.

A table in Spectrum (1992) shows that most of the big LEO applicants wished to use the band 1,610 - 1,625.5 MHz for uplinks and the band 2,483.5 - 2,500 MHz for downlinks. The exception shown was that Iridium planned to use 1,610 - 1,625.5 MHz for both uplinks and downlinks. These uplink and downlink frequencies are the first pair of the lower portion of Table 1. The U.S. was succesfull in obtaining these desired allocations. In Minuta (1992), U.S. delegation member Leslie Taylor is quoted as pointing out that Iridium may have a need to coordinate with the Russian global positioning system and that this could impinge on Motorala's plans as Motorola has proposed to use only the 1,600 MHz spectrum where the Russian system operates.

WARC 92 adopted Resolution COM 5/11 that invited the technical bodies of the ITU to carry out technical, legal, and operational studies leading to the establishment of standards governing the operation of LEO's. The Resolution noted that only a very limited number of LEO systems offering worldwide coverage can coexist in any given frequency band and that there are at present no standards for the coordination, sharing, and operation of such systems.

3. Broadcasting Satellite Service (BSS)

Both Sound and HDTV are included under this heading. The U.S. proposal for BSS (Sound) was for the use of the 2,310 - 2,360 MHz band. It did not succeed with this proposal on a worldwide basis, but the band is authorized for the U.S. and India on a country footnote basis. The band 1,452 - 1,492 MHz was allocated on a worldwide basis for BSS Sound, exclusively for digital audio broadcasting and subject to provisions of Resolution COM 4/W. This resolution calls for convening another WARC not later than 1998 to plan for BSS Sound and complementary terrestrial service, as it was not possible to resolve satisfactorily in WARC 92 all of the questions and competing demands. An allocation of 2,535 - 2,655 MHz was made by country footnote for use in several Asian countries, including China, Japan, India and the the members of the Russian Federation. The upper 25 MHz of all allocations is available immediately (before the planned 1998 WARC). The U.S. proposal for HDTV was for use of the 24.65 - 25.25 GHz band, but instead an allocation of 17.3 - 17.8 GHz was made for Region 2, which the U.S. is in. For Regions 1 and 3, the allocation is for 21.4 - 22.0 GHz. No compromise was found for a unique worldwide allocation for wideband HDTV.

In a May, 1992 report on WARC 92 in Satellite Communications (Manuta, 1992), a spokesperson for the National Association of Broadcasters (NAB) is quoted as saying that they regard the allocation near 1,500 MHz as a " threat to our system of local over-the-air terrestrial broadcasting." The NAB expects that the Canadian and Mexican governments and U.S. receiver manufacturers will put the U.S. government under pressure to adjust to the worldwide assignment near 1,500 MHz by moving U.S. military telemetry operation from 1,500 MHz to 2,300 MHz.

4. Space Services

A comparison between U.S. proposals and WARC 92 decisions for Space Services Above 20 GHz is shown in Table 3. The U.S. was sucesssful in obtaining a satisfactory allocation for Uplink Power Control Beacons as shown by Ann Heyward in the last two viewgraphs of the following section. Allocations for Mobile-Satellite Service (MSS) were made on a Primary Worldwide basis for 20.1 - 20.2 GHz and for Region 2, Primary, at 19.7 - 20.1 GHz. Also 29.5 - 29.9 GHz, Region 2 and 29.9 - 30 GHz, Worldwide received Primary allocations. U.S. proposals for Space Research were generally succesful. A Primary allocation at 2 GHz was made for spacecraft command, control, and data acquisition. The first-ever allocations for communications between astronauts and their base spacecraft during extra vehicular activities was made near 400 MHz. The 25.25 - 27.5 GHz Primary allocation for Inter-Satellite service of Table 3 can be used for the Tracking and Data Relay Satellite. The Primary Deep Space allocations around 32 and 34 GHz can be used for the next generation of planetary exploratory deep-space probes. Allocations at 37 and 40 GHz can be used for future manned missions, such as missions to the Moon and to Mars.

4. Implications for Radiowave Propagation

There is much competition for allocations in the 1-3 GHz frequency band. The "big" LEO systems discussed in section 2 plan to use allocations in the 1-3 GHz band, and the band is generally favored for Mobile-Satellite Service (MSS). An allocation at 2 GHz for spacecraft command, control, and data acquisition was mentioned above, and the Global Positioning System (GPS) operates in the band. Although BSS Sound is to be considered further in a later WARC, WARC 92 made allocations for BSS Sound in the 1-3 GHz band. The importance of the 1-3 GHz band indicates that continuing attention to modeling of propagation and interference in the band is called for. With respect to interference, consideration needs to be given to sources of interference, criteria for sharing, and modulation techniques. The use of CDMA appears to

Table 3. SPACE SERVICES ABOVE 20 GHz

WARC '92 Comparison Matrix	
Space Services Above 20 GHz	
U.S. Proposal	**WARC '92 Decision**
19.7 - 20.2 GHz ↓ (Primary) General-Satellite	19.7 - 20.1 GHz ↓ (Region 2) Mobile-Satellite upgraded to Primary
	20.1 - 20.2 GHz ↓ (Worldwide) Mobile-Satellite upgraded to Primary
21.7 - 22 GHz (Primary) Inter-Satellite	22.55 - 23 GHz (Primary)
	24.45 - 24.65 GHz (Primary) Inter-Satellite
24.55 - 24.65 GHz ↑ (Primary) Radiolocation-Satellite	24.65 - 24.75 GHz ↑ (Primary)
25.25 - 27.5 GHz (Primary) Inter-Satellite	25.25 - 27.5 GHz (Primary)
	25.5 - 27 GHz ↓ (Secondary) Earth Exploration-Satellite
27.5 - 29.5 GHz ↓ (Primary) Fixed-Satellite Power Control Beacons	27.5 - 27.501 GHz ↓ (Primary)
	27.501 - 29.999 GHz ↓ (Secondary)
	29.999 - 30 GHz ↓ (Primary)
	28.5 - 30 GHz ↑ (Secondary) Earth Exploration-Satellite
29.5 - 30 GHz ↑ (Primary) General-Satellite	29.5 - 29.9 GHz ↑ (Region 2) Mobile-Satellite upgraded to Primary
	29.9 - 30 GHz ↑ (Worldwide) Mobile-Satellite upgraded to Primary
31.8 - 32.3 GHz ↓ (Primary) Space Research (Deep Space)	31.8 - 32.3 GHz ↓ (Primary)
34.2 - 34.7 GHz ↑ (Primary) Space Research (Deep Space)	34.2 - 34.7 GHz ↑ (Primary)
37 - 38 GHz ↓ (Primary) Space Research	37 - 38 GHz ↓ (Primary)
	37.5 - 40.5 ↓ (Secondary) Earth Exploration-Satellite
39.5 - 40.5 GHz ↑ (Primary) Space Research	40 - 40.5 GHz ↑ (Primary)

have significant advantages, a point apparently recognized by three of the five big LEO systems mentioned in Sec. 2 who list CDMA under "Type of Signal". LEO as well as GEO systems are influenced by the Earth's ionosphere and may require attention to ionospheric scintillation. The quite low 1-3 GHz frequency range in particular is subject to some degree of ionospheric scintillation, especially in equatorial regions and at high latitudes (Davies, 1991). Ionospheric scintillation decreases with increasing frequency and tends not to be important at frequencies near 10 GHz and higher.

Because of the congestion of the 1-3 GHz band and the availability of wider bandwidths at higher frequencies, however, upward moves in frequency from 1-3 GHz may very well occur. The NASA Propagation Program has, of course, been very much involved in the ACTS Program which involves an upward move to the 20 and 30 GHz frequencies. We have learned from an informed source that attention is now being given to a similar upward move in the case of a certain LEO system.

Attention is now being given to providing worldwide coverage by communication systems, such that it may soon be possible to communicate from any point on the Earth's surface to any other point on the Earth's surface. Thus an increasing orientation towards worldwide coverage seems to be appropriate. Much attention has been given to communication in east-west directions up to now. But in the case of the United States, we sense increasing interest in communication in the north-south direction from the U.S. to and from Central and South America. Cooperative research programs involving propagation in, and to and from, the southern portion of the western hemisphere may well prove fruitful.

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