Prospects And Limitations For Use Of Frequency Spectrum From 40 To 300 GHz

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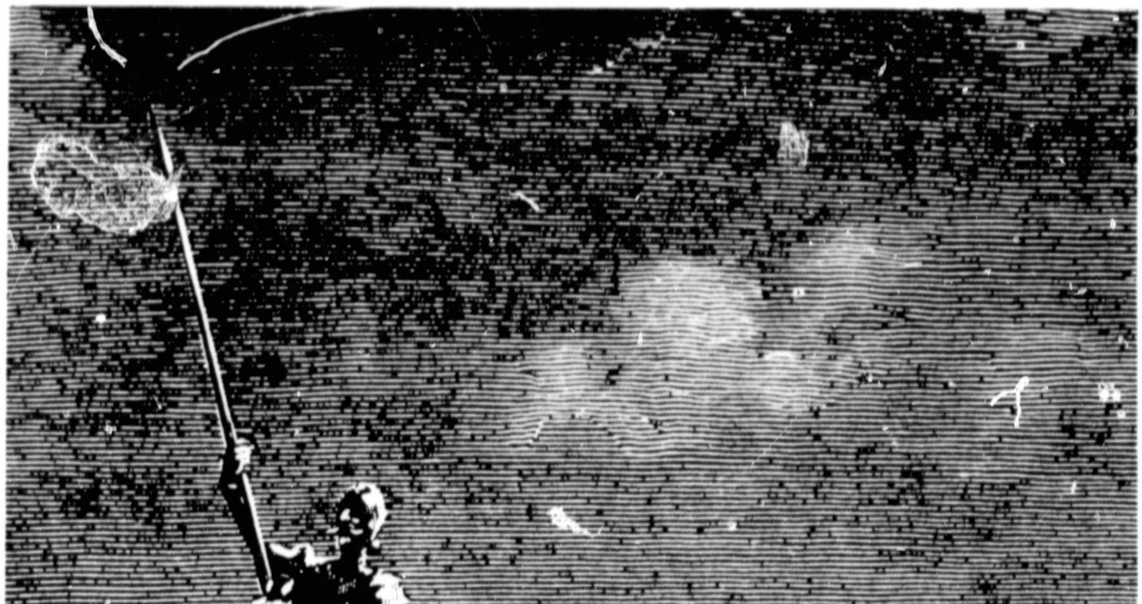


Clarence E. Catoe

An exploded view depicting the legendary Spanish folk hero, Don Quixote, taken from one of the more than 231 lithograph prints produced from the collaboration of Gustave Dore, the illustrator, and Heliodore Joseph Pisan, the engraver, in 1880.

PROSPECTS AND LIMITATIONS FOR USE OF FREQUENCY SPECTRUM FROM 40 TO 300 GHz

By Clarence E. Catoe

1. Introduction

One of the exploratory issues that will be addressed during the 1979 General World Administrative Radio Conference (GWARC) in Geneva, Switzerland, concerns the existing and future use of the electromagnetic spectrum from 40 to 300 gigahertz (GHz), i.e., .75 of a centimeter to 1 millimeter, respectively. The discussions on this particular issue are very important, because they represent potential growth areas for services that cannot be accommodated in our present increasingly crowded spectrum space. The decisions reached at Geneva will go a long way toward determining the kinds of technology and types of services that will emerge during the next twenty years. Much of the attention on this issue will be centered on trying to provide answers on how the spectrum space will be allocated in terms of services. The activities envisioned for this segment of the electromagnetic spectrum fall generically into two basic categories: communications and remote sensing.

The communications services considered for this region are focused on the existing and future frequency allocations that are required for terrestrial radio services, space-to-ground radio services, space-to-space radio services, and space-to-deep space radio services.

The remote sensing services considered for this region can be divided into two basic goups of activities: earth-viewing and space-viewing. The earth-viewing activities are those in which passive, and/or active microwave techniques will be used to monitor either terrestrial, or atmospheric phenomena; whereas, the space-viewing activities, i.e., radio astronomy, are those in which passive microwave techniques will be used to monitor the natural emission coming from celestial objects. In this paper, the total spectrum space from 40 to 300 GHz will be surveyed in order to identify potential service mixes between communications and remote sensing that could be successfully accommodated within this band.

2. Background Constraints

Above 40 GHz, atmospheric attenuation becomes more prominent.[1] Oxygen and water vapor act as major deterrents to communications and remote sensing as indicated in Figure 1. Nevertheless, successful operation is generally possible in certain areas which are designated as "window regions." In these window regions, the atmospheric attenuation effects which tend to prohibit any kind of operation are substantially reduced. Except for the line emission measurements which are associated with trace constituent gases, the bulk of the communications and remote sensing needs all appear to be clustered around these window regions. It is this competition for the same space by both communications and remote sensing, which directly impacts the frequency allocation and sharing criteria.

3. Communications

In the communications arena, a definite need exists for frequencies and for research and experiments related to direct broadcast satellite service (BSS) and fixed satellite service (FSS).

3.1 Broadcast Satellite Service And Fixed Satellite Service

Present allocations for BSS above 40 GHz are at 41-43 GHz and 84-86 GHz. Both of these frequency bands are exclusively

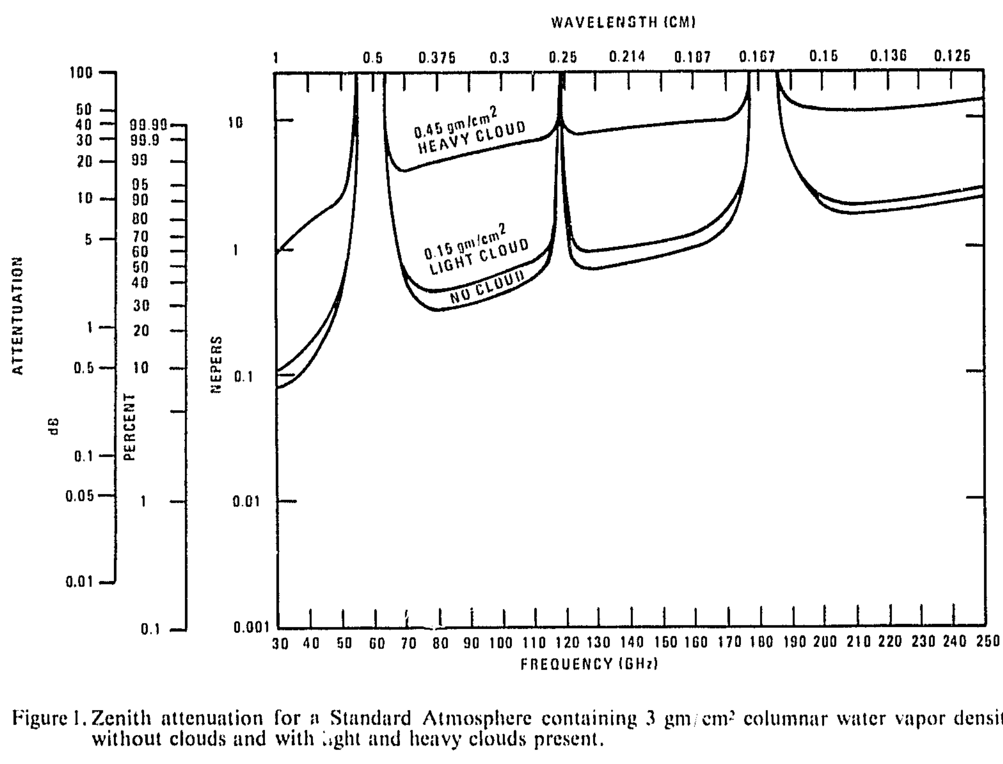


Figure 1. Zenith attenuation for a Standard Atmosphere containing 3 gm/cm² columnar water vapor density without clouds and with light and heavy clouds present.

for BSS use. However, the developing United States position for the 1979 World Administrative Radio Conference (WARC), as reflected by the 8th Notice of inquiry relative to the WARC, proposes sharing both of these bands with terrestrial fixed and mobile services. It is considered that limited sharing will be technically possible; however ground receivers in the BSS can not be placed within the main beam of terrestrial transmitters in the fixed service.[2] This condition should limit the development of BSS systems at these frequencies. The question of whether or not to oppose this view hinges upon the expected rates of implementation of the BSS, fixed and mobile services at these frequencies.

At present, operational broadcasting satellites for the United States are not yet beyond the preliminary planning stage at 12 GHz. Before a firm need is established at 40 and 80 GHz for the BSS, the 12 GHz band would have to show evidence of being filled. This has not happened; nevertheless, it is expected to occur in the late 1980's due to the transition of many of the application's experiments, such as earth resources missions, into viable operational missions.[3] By the late 1990's, it is assumed that the user community will expand to completely fill the next highest frequency band at 30/20 GHz which are allocated for this purpose. The next logical bands after 30/20 GHz are filled would be 40 and 80 GHz. However, if the need does not develop, then the way is clear for domestic use of these frequencies for terrestrial services. The proposed sharing at 40 and 80 GHz appears to allow the greatest flexibility to satisfy the future needs for either the BSS or terrestrial service in these bands.

Present allocations for the FSS above 40 GHz as well as those proposed in the 8th Notice of Inquiry are shown in Table IA. The general approach to the proposed allocations appears to have been: (1) to increase the bandwidth available to the FSS, and (2) to provide shared allocations rather than exclusive allocations. This approach appears adequate to meet all projected needs of the FSS as well as the terrestrial services, provided that domestically we provide control over frequency use and make bandwidths available on an exclusive basis where sharing is not possible.[4]

3.2 *Orbiting Deep Space Relay Station*

Another area in which frequency allocations will be needed is in the planetary research. It is considered that future missions to the outer planets and beyond, which are in the preliminary planning state now, will require increased telecommunications performance. This requirement is due to the fact that many of these missions will use sophisticated high data rate sensors. These higher data rates in turn would require new frequencies. This activity as currently conceived could also require the use of an Orbiting Deep Space Relay Station (ODSRS). An artist's concept of the ODSRS[5] is given in Figure 2. Six frequency allocations were proposed for this particular task,[6] but only four of those recommended fall in the region above 40 GHz. These proposed allocations are given in Table IB.

In general, the sharing criteria for deep space research are given in CCIR Doc. 2/279. These criteria were used as a basis for the selection of ODSRS frequency bands. For communication links between the satellite and the spacecraft that are shielded from terrestrial signals in deep space, sharing is possible except with services utilizing transmitters, or receivers located outside the shielding atmosphere. For earth-to-space and satellite-to-space links that are not shielded from terrestrial signals, the sharing criteria of Doc. 2/279 also apply.

ODSRS CONFIGURATION

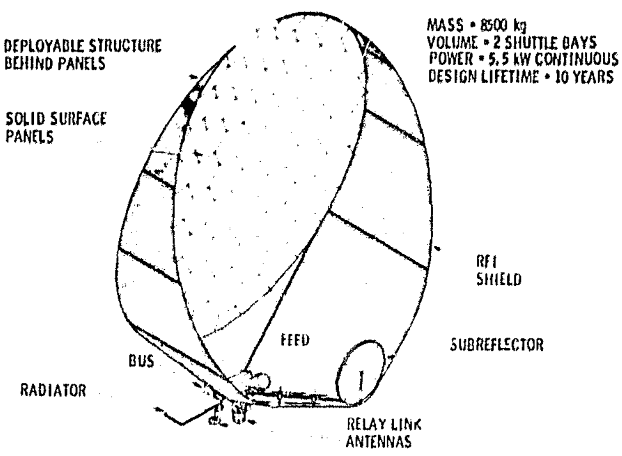


Figure 2. Orbiting Deep Space Relay Station

Basically the frequencies to be avoided by the ODSRS communication links are those that are required for passive and active remote sensing of the earth and those that are required for radio astronomy (CCIR Doc 2/262 (Rev1), 1977). In terms of the proposed ODSRS frequencies, interference is possible at 102-102.5 GHz, which coincides with the 1st molecular resonance of nitrous oxide. In addition, the next higher frequency band at 118.7-119.2 GHz intrudes upon the 105-126 region, which is set aside for passive research and coincides with the oxygen line that occurs at 118.75 GHz.

4. Remote Sensing

Remote sensing in the generic sense refers to the process of detecting, identifying, and monitoring an event or an object by virtue of the energy that it emitts, reflects, or absorbs. It is usually from the inferences obtained from such remote measurements that the solutions to many of our remote observational problems can be obtained. As indicated previously, above 40 GHz atmospheric attenuation is a serious problem except in "window regions". The frequency allocations that are needed for both earth-viewing and space-viewing are given in Table IIA and Table IIB, respectively.

4.1 *Remote Sensing Of Earth*

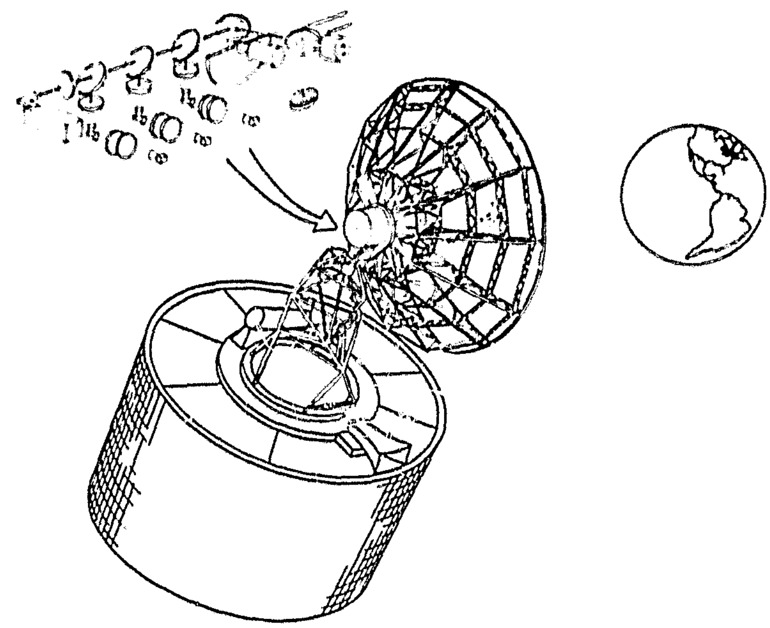
In the earth-viewing mode, microwave sensors can measure either the emission from the earth, or the line emission from trace gases within the planetary atmosphere. At present, there is so much uncertainty concerning our understanding of the physical and chemical processes that occur in nature that cause weather, and the potential impact of various atmospheric pollutants on the entire weather and climate process. High resolution microwave satellite systems show promise, for the first time, of measuring and mapping with useful accuracy the dynamic structure of the earth's atmosphere. For example, in the case of severe storms, microwaves can penetrate most clouds and yield information on: (1) atmospheric temperature profile estimate with 1-5km accuracy, (2) precipitable water vapor over the ocean with 0.1-0.4 cm rms accuracy, (3) liquid water over the

TABLE I – COMMUNICATIONS REQUIREMENTS

EXISTING		PROPOSED	
FREQUENCY (GHz)	ALLOCATIONS	FREQUENCY (GHz)	ALLOCATIONS (8th NOI)
A. Fixed Satellite Service Allocations			
40–41	FIXED-SATELLITE (Space-to-Earth)	40–41	FIXED-SATELLITE (Space-to-Earth) FIXED MOBILE MOBILE-SATELLITE (Space-to-Earth)
43–45	AERONAUTICAL MOBILE-SATELLITE MARITIME MOBILE-SATELLITE AERONAUTICAL RADIONAVIGATION-SATELLITE MARITIME RADIONAVIGATION-SATELLITE	43–45	FIXED-SATELLITE (Earth-to-Space) MOBILE-SATELLITE (Earth-to-Space)
50–51	FIXED-SATELLITE (Earth-to-Space)	50.–50.2	FIXED FIXED-SATELLITE (Earth-to-Space) MOBILE
		50.2–50.4	FIXED FIXED-SATELLITE (Earth-to-Space) MOBILE SPACE RESEARCH (Passive) EARTH EXPLORATION-SATELLITE (Passive)
		50.4–51	FIXED-SATELLITE (Earth-to-Space) FIXED MOBILE MOBILE-SATELLITE (Earth-to-Space)
51–51.4	EARTH EXPLORATION-SATELLITE SPACE RESEARCH	51–51.4	FIXED MOBILE FIXED-SATELLITE (Earth-to-Space) MOBILE-SATELLITE (Earth-to-Space)
71–84	(Not allocated)	71–74	FIXED-SATELLITE (Earth-to-Space) MOBILE-SATELLITE (Earth-to-Space) FIXED MOBILE
		81–84	MOBILE-SATELLITE (Space-to-Earth) FIXED-SATELLITE (Space-to-Earth) FIXED MOBILE
92–95	FIXED-SATELLITE (Earth-to-Space)	92–95	RADIOLOCATION FIXED-SATELLITE (Earth-to-Space) FIXED MOBILE
102–105	FIXED-SATELLITE (Space-to-Earth)	102–105	FIXED-SATELLITE (Space-to-Earth) FIXED MOBILE
140–142	FIXED-SATELLITE (Earth-to-Space)	140–142	FIXED-SATELLITE (Space-to-Earth) FIXED MOBILE
150–152	FIXED-SATELLITE (Space-to-Earth)	150–151	FIXED-SATELLITE (Space-to-Earth) FIXED MOBILE SPACE RESEARCH (Passive) EARTH EXPLORATION-SATELLITE (Passive)
		151–152	FIXED-SATELLITE (Space-to-Earth) FIXED MOBILE
152–170	(Not allocated)	152–164	FIXED MOBILE FIXED-SATELLITE (Space-to-Earth)
		164–165	FIXED MOBILE FIXED-SATELLITE (Space-to-Earth) SPACE RESEARCH (Passive) EARTH EXPLORATION-SATELLITE (Passive)

TABLE I (CONTINUED)

EXISTING		PROPOSED	
FREQUENCY (GHz)	ALLOCATIONS	FREQUENCY (GHz)	ALLOCATIONS (8th NOI)
A. Fixed Satellite Service Allocations (Continued)			
200-220	(Not allocated)	201.5-217	FIXED-SATELLITE (Earth-to-Space) FIXED MOBILE
220-230	FIXED-SATELLITE	220-221	FIXED-SATELLITE FIXED MOBILE (Except aeronautical mobile) RADIO ASTRONOMY
		221-225	FIXED-SATELLITE (Space-to-Earth) FIXED MOBILE RADIOLOCATION
		225-227	FIXED-SATELLITE (Space-to-Earth) FIXED MOBILE SPACE RESEARCH (Passive) EARTH EXPLORATION-SATELLITE (Passive) RADIOLOCATION
		227-229	FIXED-SATELLITE (Space-to-Earth) FIXED MOBILE RADIOLOCATION
		229-230	FIXED MOBILE (Except aeronautical mobile) RADIO ASTRONOMY SPACE RESEARCH (Passive) EARTH EXPLORATION-SATELLITE (Passive)
265-275	FIXED-SATELLITE	265-275	FIXED-SATELLITE (Earth-to-Space) FIXED MOBILE
B. Orbiting Deep Space Relay Station			
30.01-37.75	FIXED 228 229 231 MOBILE 233A	31.8-32.3	RADIONAVIGATION SPACE RESEARCH (Deep Space-to-Near Earth Satellite, and Deep Space-to-Earth) 412B
		39.5-40	SPACE RESEARCH (Earth-to-Deep Space and Near-Earth Satellite-to-Deep Space)
38.25-41.00	FIXED 228 229 231 MOBILE RADIO ASTRONOMY 233B		FIXED MOBILE 391A
54.00-68.00	FIXED 228 237 MOBILE BROADCASTING	59.0-59.5	FIXED MOBILE SPACE RESEARCH (Deep Space-to-Near Earth Satellite)
		63.5-64.0	FIXED MOBILE SPACE RESEARCH (Near Earth Satellite-to-Deep Space)
103-105	FIXED SATELLITE (Space-to-Earth)	102-102.5	SPACE RESEARCH (Near Earth Satellite-to-Deep Space) FIXED MOBILE
117.97-121.95	AERONAUTICAL MOBILE	118.7-119.2	SPACE RESEARCH (Deep Space-to-Near Earth Satellite) SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive) FIXED MOBILE



BAND (GHz)	NUMBER OF CHANNELS	NOMINAL RESOLUTION (km)	SENSITIVITY (°K)	FUNCTION (800 x 800 km MAPS IN 1/2 HOUR)
183	6	25	0.2	WATER VAPOR PROFILE
140	1	32	0.1	LIQUID WATER
118	11	38	0.1-0.4	TEMPERATURE PROFILE 0-30 km, PRECIPITATION OVER LAND
104	1	45	0.1	WINDOW, PRECIPITATION

Figure 3. Geosynchronous Microwave Atmosphere Sounding Radiometer (MASR).

ocean with 20.1 cm rms accuracy, and (4) precipitation rates, surface winds over the ocean, and oceanic surface temperatures with accuracies sufficient to define the character of meteorological situations. In Figure 3, an example of the type of instrument that might be useful in collecting the desired information is given.

The extension of microwave technology to the submillimeter wavelengths will allow more important measurements to be made. The normal observations made by these techniques will allow continuous global coverage of atmospheric thermal emission. Microwave techniques are particularly well-suited for line emission from trace gases[7-19], because the spectral lines observed remain in thermal equilibrium throughout the region; consequently, the widths of these lines are well suited for instrumentation. For example, atmospheric temperatures can be measured at altitudes of 10-110 km, and variables such as wind, pressure reference levels, magnetic fields, and the relative abundance of such gases as O, O_2, O_3, CO, NO ClO, OH, H_2O, H_2O_2, N_2O, NO_2, HNO_3, CH_4 and others can be measured over portions of this range with accuracies generally exceeding those available using other techniques. Such uniquely accurate data could significantly increase man's understanding of the stratosphere, mesosphere, and lower thermosphere. The above mentioned microwave data could be very useful in two ways: (1) in helping define precursor conditions useful as inputs to dynamic and statistical models to aid in the prediction, understanding, and possible modification of weather, and (2) to test new concepts of detecting and monitoring atmospheric pollutants.[20]

The frequency allocations that are required for the above mentioned measurements are as follows:

44.8 GHz: (Active Sensors). Used for atmospheric pressure measurements. Falls within band for Fixed and Mobile Earth communications. No problems anticipated until these services become operational.

50.2-50.4 GHz: (Passive Sensors) Used for atmospheric temperature measurements. Operates in band designated for Fixed-Satellite communications for Earth-to-Space links. Interference will occur when Fixed-Satellite operation begins. Measurements can be performed at other frequencies.

51.4-59.0 GHz: (Passive Sensors) Critical band for atmospheric temperature measurements at 52-54.25 GHz and 58.2-59 GHz.

TABLE II – REMOTE SENSING REQUIREMENTS

FREQUENCY BANDS (GHz)	BANDWIDTH (MHz)	PRINCIPAL MEASUREMENTS	TYPE OF ALLOCATION	INCLUDED IN FCC (8th NOI)	IMPOR-TANCE	ASSESSMENT
A. Earth Viewing Service Allocations (Passive and Active Sensors)						
Passive Sensors						
50.2-50.4	200	Atmospheric temperature	Primary	Yes	2	Band will be used by TIROS-N for atmospheric temperature measurements. Areas at interference would occur when Fixed-Satellite begins to use band for earth-to-space links. Future sensors could perform measurements at other frequencies if required. IUCAF supports.
51.4-59.0	7600	Atmospheric temperature	Primary	Yes	1	Critical band for atmospheric temperature measurement. 52-54.25 and 58.2-59 GHz currently allocated for passive research. No known problems since sharing is feasible with proposed services. IUCAF supports wideband for space research.
64-65	1000	Atmospheric temperature	Primary	Yes	1	Atmospheric temperature measurement. U.S. proposes exclusive allocation for passive use. No known problems in obtaining allocation. Currently space research band. IUCAF supports.
86-92	6000	Clouds; Oil spills; Ice; Snow	Primary	Yes	1	Very important band for surface measurements. Highest frequency band likely to be used for surface measurements and also has widest bandwidth. Currently Radio Astronomy and Space Research (passive) band. U.K. may oppose part of band for passive purposes.
100-102	2000	Nitrous oxide	Primary	Yes	1	First molecular resonance for measurement of nitrous oxide. There could be opposition to 100-101 GHz portion because U.S. is proposing deletion of existing, incompatible allocations. 101-102 GHz is currently allocated for passive use.
105-126	21000	Ozone; Carbon monoxide; Atmospheric temperature; Nitrous oxide	Primary	Yes	1	Critical band for atmospheric measurements. Sharing is feasible in shared part of band (116-126 GHz). U.K. may only agree to secondary allocation. IUCAF support.
150-151	1000	Nitrous oxide	Primary	Yes	2	No known problems.
164-168	4000	Chlorine oxide	Primary	Yes	1	Important for measurement of chlorine oxide. No known problems in obtaining allocation. Interference could develop if radiolocation ever uses 165-168 GHz as proposed by U.S. Not a near-term problem.
174.5-176.5	2000	Nitrous oxide	Primary	Yes	2	No known problems.
182-185	3000	Water vapor; Ozone	Primary	Yes	1	Very important due to strong water vapor molecular line. Currently allocated for passive use. U.K. may oppose.
200-201.5	1500	Nitrous oxide	Primary	Yes	2	No known problems.
225-227	2000	Nitrous oxide	Primary	Yes	2	No known problems.
229-240	11000	Carbon monoxide; Ozone	Primary	Yes	1	No known problems. 230-240 GHz is currently allocated for passive use.
250-252	2000	Nitrous oxide	Primary	Yes	2	There could be opposition to this band because U.S. is proposing deletion of existing, incompatible services. It took two years to obtain FCC agreement.
275-277	2000	Nitrous oxide	Primary	Yes	2	No known problems.
300-303	3000	Nitrous oxide	Primary	–	2	Allocations will probably not be made above 300 GHz at the 1979 WARC. None are being proposed by the U.S.

TABLE II – (CONTINUED)

FREQUENCY BANDS (GHz)	BANDWIDTH (MHz)	PRINCIPAL MEASUREMENTS	TYPE OF ALLOCATION	INCLUDED IN FCC (8th NOI)	IMPORTANCE	ASSESSMENT
A. Earth Viewing Service Allocations (Continued)						
Active Sensors						
44.8 52.8 67.51 73.01	.1 .1 .1 .1	Atmospheric Pressure	Secondary Primary Primary Secondary	No No No No	2 1 1 2	Atmospheric pressure measurement based upon two frequencies. Pressure measurement insensitive to atmospheric temperature profile, water vapor content, cloud cover, and sea state. 52.8 GHz most important frequency for pressure sensing and is within the band required for passive atmospheric temperature sensing. Simultaneous operation on same satellite not possible due to interference, but there should be no interference between separate satellites. The 44.8 GHz, and 73.01 GHz fall within band specified for fixed and mobile Earth communications and Earth to Space links. No problems anticipated until communications service comes on line. Operation could be limited to use over oceans.
76-77	1000	Cloud monitor	Primary	Yes	2	No known problems.
B. Space Viewing Service Allocations (Passive Sensors)						
86-92	600	Celestial Observations	Primary	Yes	1	Best high frequency region where both continuum and line observations of celestial objects can be made. Band near atmospheric absorption minimum which contains at least 20 newly discovered spectral lines.
105-116 or 108-116	11000	Interstellar Carbon Monoxide	Primary	No	1	Very important for the measurement of interstellar carbon monoxide and its isotopes.
115.16-115.38	220	Interstellar Carbon Monoxide	Primary	Yes	1	Very important for the measurement of interstellar carbon monoxide whose primary line at 115.271 GHz plays an important role in the chemistry of the interstellar medium.
130-140	10000	Celestial Observations	Primary	Yes	2	An important primary allocation shared with space research (passive). Present band has good width can be used to study the molecular emission of silicone monoxide and sulfur monoxide; however, most lines of great astrophysical interest not covered in band. The possibility of an exchange should be explored. The band 106-116 GHz contains a large number of most interesting molecular lines.
144.88-144.98	100	Deuterium Cyanide	Primary	No	1	Radio astronomy observations of important spectral line due to deuterium cyanide is being carried out by a number of countries under national arrangements. Frequency band 142-150 GHz assigned for ship, position, aircraft, and air traffic control communications. Harmful interference when communications service become operational.
217-221 229-231	4000 2000	Interstellar Carbon Monoxide	Primary	No No	2 1	No known problems. 230-240 GHz is currently allocated for passive use.
230-240	10000	Celestial Objects	Primary	Yes	1	Very important atmosphere window for celestial observations, shared with space research (passive). No known problems or significant emissions in this region.

TABLE II – (CONTINUED)

FREQUENCY BANDS (GHz)	BANDWIDTH (MHz)	PRINCIPAL MEASUREMENTS	TYPE OF ALLOCATIONS	INCLUDED IN FCC (8th NOI)	IMPOR-TANCE	ASSESSMENT
B. Space Viewing Service Allocations (Continued)						
261-272.5	11500	Ethyl Radical, Cyanide, Isocyanic Acid, Formal dehyde Ion	Primary	No	1	Worldwide exclusive allocation sought, since a series of important lines falls in the range, i.e., C_2H, HCN, HCO^+, and HNC.
275-1000		Diatomic Hydrides Multiatomic Hydrides	Primary	No	2	A large number of diatomic hydrides both ionized and neutral, and a few multiatomic hydrides of astrophysical interest occur in this region.

No problems exist with proposed communication services; however, problem may exist with active sensor proposed for 52.8 GHz.

52.8 GHz: (Active Sensors) Most important frequency for pressure sensing. Interference possible if passive sensors operating from 51.4-59.0 GHz are on the same satellite. No interference anticipated between separate satellites.

64-65 GHz: (Passive Sensors) Used for atmospheric temperature measurements. No known problems in obtaining frequency allocation.

67.51 GHz: (Active Sensors) Used for atmospheric pressure measurements. Falls within the 66-71 GHz band proposed for Aeronautical and Maritime use. Narrow bandwidth of 100 KHz make frequency sharing possible. No problems until proposed Aeronautical and Maritime links become operational.

73.01 GHz: (Active Sensors) Used for atmospheric temperature measurements. Falls within the band specified for Fixed and Mobile Earth communications and Earth-to-Space links. Interference problems anticipated when communication links become operational.

76-77 GHz: (Active Sensors) Used for cloud monitoring. No known problems.

86-92 GHz: (Passive Sensors) Very important band for surface measurements in the "atmospheric window." Shares this band with Radio Astronomy. No known interference problems.

100-102 GHz: (Passive Sensors) Used for making atmospheric measurements of ozone, carbon monoxide, atmospheric temperatures, and nitrous oxide.

150-151 GHZ: (Passive Sensors) Used for atmospheric measurements of nitrous oxide. No known problems.

164-168 GHz: (Passive Sensors) Used for atmospheric measurements of chlorine oxide. No known problems in obtaining frequency allocations. Interference could develop if radiolocation ever uses 165-168 GHz as proposed by the U.S.

174.5-176.5 GHz: (Passive Sensors) Used for atmospheric measurements of nitrous oxide. No known problems.

182-185 GHz: (Passive Sensors) Used for measurements of water vapor molecular line and ozone.

200-201.5 GHz: (Passive Sensors) Used for measurements of stratospheric nitrous oxide. No known problems.

225-227 GHz: (Passive Sensors) Used for measurements of stratospheric nitrous oxide. No known problems.

229-240 GHz: (Passive Sensors) Used for measurements of upper atmospheric carbon monoxide and ozone. No known problems.

250-252 GHz: (Passive Sensors) Used for measurements of upper atmospheric nitrous oxide. Could be opposition to this band because the U.S. is proposing the deletion of incompatible services.

275-277 GHz: Used for measurements of upper atmospheric nitrous oxide. No known problems.

300-303 GHz: Used for measurements of upper atmospheric nitrous oxide. No known problems.

Most of the frequency allocations above 40 GHz for remote earth sensing are focused on developing useful information which is required for more efficient synoptic meteorological models. The potential users of this weather and climate related data are the operational weather forecasting centers and research institutions around the world. When these synoptic techniques are perfected, foreign access to the meteorological data can easily be obtained through several different channels, such as: The National Space Science Data Centers, and the World Meteorological Organization (WMO). WMO is an agency of the United Nations that already has a networking structure in place to rapidly disseminate the space acquired data. The networking structure consists very high capacity telecommunication links to the three World Meteorological Centers, and eight Regional Telecommunication Hubs.

4.2 Remote Sensing of Space

The current needs for frequency allocations above 40 GHz for radio astronomy are based on the experience with the present allocations, new astrophysical discoveries, and improved technical capabilities. Where changes in allocations are recommended, it is done with a view to the continuation of first rate research. In general, the criteria used to specify the allocations of line and continuum frequencies in radio astroomy are twofold: (1) For the continuum observers, exclusive allocations with adequate bandwidths are needed, located approximately at every octave throughout the electromagnetic spectrum. (2) Major spectral lines should have exclusive allocations that are wide enough to allow galactic and extragalactic research to be carried out.

The existing and future frequency allocations required for radio astronomy which use passive techniques [21-26] are as follows:

86-92 GHz: Used for continuum and line observations of celestial objects. This band contains at least twenty newly discovered spectral lines which are protected. Sharing is possible with passive earth remote sensing. No known problems in obtaining frequency allocation.

115.16-115.3.8 GHz: Very important for the measurement of interstellar carbon monoxide. No known problems in obtaining frequency allocation.

105-116 GHz: Very important for the study of carbon
108-116 GHz: monoxide and its isotopes. This region contains a large number of interesting molecular lines.

144.88-144.98 GHz: Used to observe important spectral line due to deurated cynanide. Measurements in this region carried out by a number of countries. Note that the frequency band 142-150 GHz is assigned for ship and aircraft, communications, position and traffic control. Harmful interference will occur when the above mentioned services become operational.

217-221 GHz: Used to observe interstellar carbon mono xide.
217-231 GHz:
229-231 GHz: No known problems.

230-240 GHz: Very important atmospheric window for celestial observations. This band is also shared with space research (passive), i.e., earth viewing. No known frequency allocation problems. Lack of spectral signatures in this region offers the possibility that this region may be abandoned for radio astronomy.

261-272 GHz: Very important spectral lines of ethynal radical, hydrogen cyanide and diazenylium. Observations are being carried in a number of countries under international arrangements. Potential interference is due to the fact that this band is also assigned to ship, aircraft, and air traffic control communications. Problems should occur when these services become operational.

Many countries around the world including Australia, Brazil, Canada, France, India, Italy, Japan, the Netherlands, the United Kingdom, the United States, Russia and West Germany have devoted large sums of money to the development of radio astronomy. It is anticipated that this support will continue, and that other countries (primarily in the Arab world and emerging African nations) will soon start major radio astronomy projects. The technology in radio astronomy is rapidly advancing and as of 1974 several observatories were capable of operating at frequencies up to 260.05 GHz. It is considered that before 1985, the enabling technology will be developed which will allow radio astronomy techniques to operate above 300 GHz and in the late 1990's operation above 1000 GHz should be possible.

5. Conclusion

In this paper I have covered in a cursory fashion some of potential service mixes that could occur in the spectral band from 40 to 300 GHz. Briefly, the services I have identified consist of communications and remote sensing. In communications, the focus was on the use of the spectrum space for Broadcast Satellite Systems, Fixed Satellite Systems, and Orbiting Deep Space Relay Stations. In remote sensing, the focus was on the use of the spectrum space for earth viewing and space viewing activities that provide more insight on our earth and our celestial environments.

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