Gateways to the 21st Century

Joe Kasser, W3/G3ZCZ
POB 3419, Silver Spring, MD., 20918, USA

Abstract

The Amateur Radio Service, about to transition into the next century is facing the loss of sections of its vhf, uhf and microwave bands to commercial services. At present radio amateur use of these bands is somewhat haphazard and uncoordinated. This paper presents an integrated plan for the use of those bands, that has the potential not only to safeguard those frequencies but to revolutionize the whole concept of amateur radio.

This article discusses how Gateways may be used to integrate amateur radio terrestrial, satellite and interplanetary microwave communications. Such an integrated capability will provide capabilities that don't exist at this time and has the potential to transform amateur radio.

The Problem

The Amateur Radio Service, about to transition into the next century is facing the loss of sections of its vhf, uhf and microwave bands to commercial services. In 1991, the Amateur radio service is still using technology based on that developed in the 1970's, with the sole exception of packet radio.

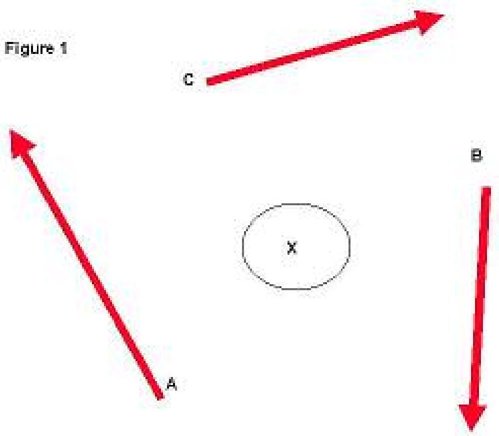
Recent advances in the state-of-the-art of computers and microwave technology have been ignored by the mainstream of radio amateurs. At present radio amateur use of these bands is somewhat haphazard and un-coordinated.

The Alternatives

There are three alternatives:-

1. Do nothing.
2. Try to increase usage of these bands without providing new services.
3. Identify a new service suited to the properties of the bands, and propose a plan to move communicators into those bands.

Figure 1



Doing nothing will not make the problem go away. The bands are there and 1.2 GHz equipment is available commercially, but few communicators are moving up to that band from the 2 meter and 70 cm bands. This is because there is little incentive to move up to 23 cm. In general the higher the frequency, the more expensive the equipment that uses it. A new technology is rarely adopted unless it provides a new (and is or quickly becomes desired) capability [1].

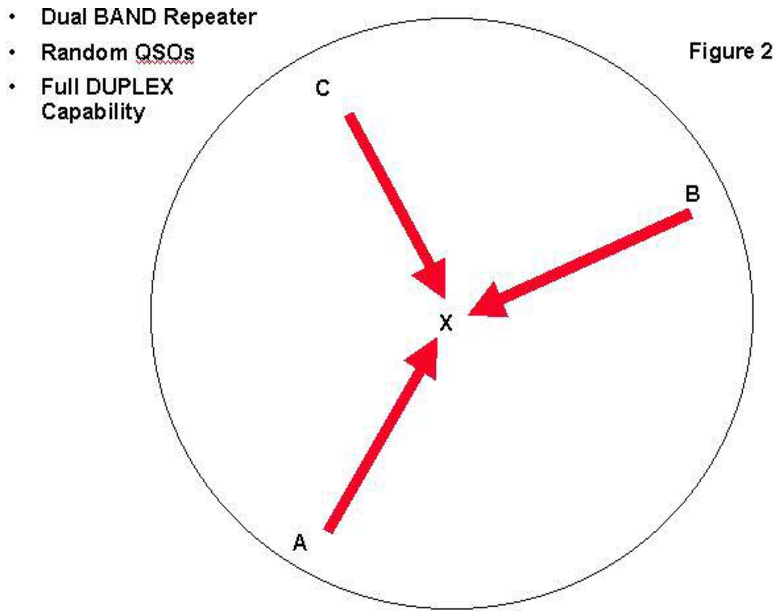
The third alternative is thus the only choice that stands a chance of increasing the occupancy of those bands. The Gateway Project Proposal is herein identified as one way of providing an incentive to move the general communicators up in frequency. It also addresses several other problematic aspects of amateur radio and provides an integrated solution.

The Gateway Project Proposal

This project identifies Gateways as a mechanism for integrating amateur radio terrestrial, satellite and interplanetary microwave communications. Such an integrated capability will provide capabilities that don't exist at this time and has the potential to transform amateur radio.

The VHF, UHF and Microwave Bands

The microwave bands are allocated to the Radio Amateur Service as secondary allocations. At present radio amateur use of these bands is somewhat haphazard and un-coordinated. Radio amateurs have the use of these frequencies providing they do not cause interference to the primary users. Sections of the 70 cm the 23 cm bands have already been lost in various countries, 220-220 Mhz has been lost in the U.S.A and the prospect of further losses face us today. Our use of the vhf, uhf and microwave bands is twofold; terrestrial and satellite.



Terrestrial Use of Microwave Bands

Random contacts (QSO) on the microwave bands are few and far between. They seem to take place either as the result of a telephone call between the stations involved, or as the result of a scheduled expedition. In the latter case, the two stations involved drive out to different mountain tops, make a contact and write it up for the national magazine. All well and good, but hardly everyday use of the band. The microwave bands are not suited for random QSOs in the same way as the lower frequency bands. Figure 1 shows a typical situation with three stations, each using highly directional antennas. The antennas are so directional that each station cannot hear another. On the other hand, if a repeater was employed as shown in Figure 2, they would be able to QSO easily enough. Repeaters are commonly used on 2 meters and 70 cm, yet they are very rare on the microwave bands. Why? Perhaps it is because microwave users tend to be experimenters, not communicators. From the experimen-ter's point of view, there is no challenge in repeater QSOs. From the communicator's point of view, a microwave repeater, as a copy of a 2 meter repeater, would not offer anything worthwhile building the equipment to use it. If we are going to make use of the microwave bands for communications, we have to do it in a way that offers something new. One such capability which seems to have been overlooked is full duplex communications.

Satellite Use of the Bands

The 2 meter and 70 cm bands are the most popular of the vhf and uhf bands. The current spacecraft in development for the amateur radio service, shown in Table 1 [2], are still planning to use these bands. The 2 meter band is very crowded in most parts of the world. There is at present already enough interference (QRM) in the satellite section of the 2 meter band. This situation is only going to get worse.

Table 1 Amateur Radio Spacecraft Currently Under Development

SPACECRAFT	COUNTRY	MISSION	LAUNCH DATE
TECHSAT	Israel	Educational Construction Project	1996
SEDSAT	USA	Transponder with science experiment.	1997
SUNSAT	S. Africa	Educational Construction Project	1997
AMSAT-PHASE 3D	Germany and an International Team	Long Life Intercontinental Communications	1997

Satellite users vocally want "Mode B" with its 70 cm uplink and 2 meter downlink, yet mode B usage through the AMSAT-OSCAR (AO) 10 and 13 spacecraft is minimal. On the other hand, mode B on AO-21 is used by the same number of stations. If the users really wanted mode B, AO-10 and AO-13, with their intercontinental range and long access times, should used by more stations than those using AO-21. It seems though that they are not. Since AO-21 is in low earth orbit, it is much easier to get a stronger signal into and out of (albeit for shorter time periods) than AO-10 and AO-13. OSCAR users who are vocally demanding "Mode B" seem to be stating the problem in terms of a specific solution. **What really they seem to be demanding is "Easy Access to communications satellites"**. They are stating it in terms of the current capability of AO-21, and their remembered capability of Mode B from AO-7.

Spacecraft Requirements

In the late 1970's, Karl Meinzer, DJ4ZC and AMSAT-DL studied the problem of providing worldwide amateur radio communications service with a single spacecraft [3]. These requirements were summarized as shown below [4].

1. All users want to get as much daily communications (operating) time as possible.
2. All users want to be able to work anybody they can (DX or local) taking advantage of the propagation characteristics of the medium (no skip zones).
3. At least 90% of the amateur radio population of the globe are located in the northern hemisphere.
4. The radio amateur population is distributed evenly over all geographic longitudes.

The optimal orbit to meet these requirements is the highly elliptical orbit, as used by the Molniya satellites. These spacecraft provide the desired communications capacity to the

Soviet Union with much the same population distribution. Unfortunately, this orbit when used to provide Mode B com-munications suffers from marginal links due to the spacecraft on board antenna and power limitations.

Let's now add the following observation to those above.

5 The majority of radio amateurs live in urban areas.

By introducing a Gateway into the communications path, users have easy access with good signal levels and do not have to worry about tracking the spacecraft. Satellite builders can build microwave communications systems. A new group can pick up the challenge of building both the gateways and designing the user equipment for accessing the Gateway. The state-of-the-art has changed.

A block diagram of the conceptual gateway is shown in Figure 3. The gateway is modular in construction. It consists of a wide band terrestrial receiver and transmitter using frequencies selected by the local gateway group. The satellite up and down link frequencies are determined by the satellite builders (in conjunction with the gateway community). The gateway is built to comply with (to be developed) International Amateur Radio Gateway Standards. The gateway also contains a terrestrial beacon which can be used to provide local news bulletins, spacecraft schedules, educational and housekeeping telemetry, etc. The gateway uses different terrestrial bands (or spacing) so that all users can receive their own transmissions.

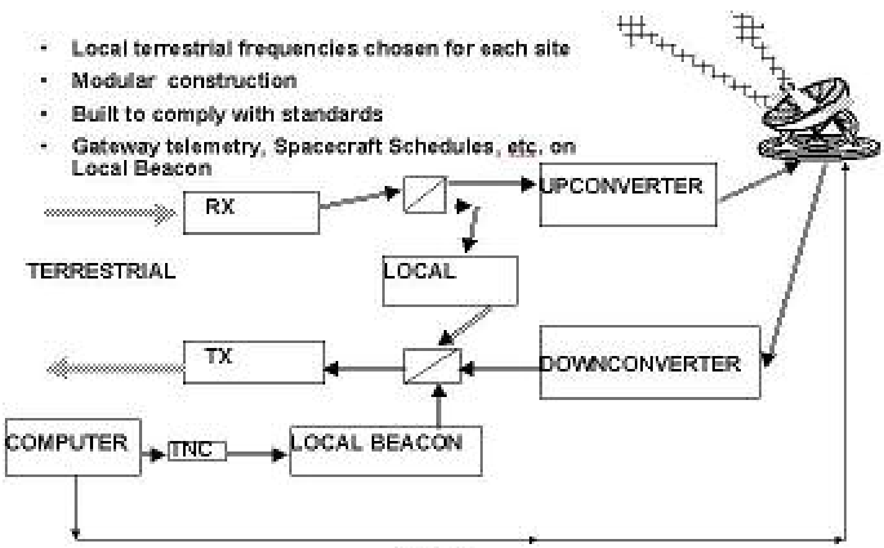


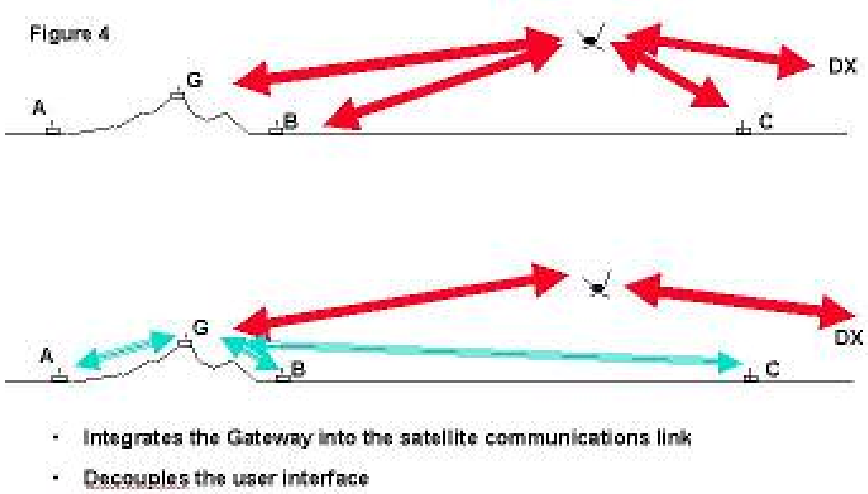
Figure 3

The Conceptual Gateway

Satellite Gateways were proposed and described by this writer in 1978 [5][6]. In the 1970's the technology to use gateways was not practical, in the 1990's it is. Consider how the gateway would work. Figure 4 shows a typical satellite usage scenario at some particular instant of time. In Figure 4A, stations A, B, C and G can access the satellite to work each other or any DX that is about. Station A is blocked by the hill that station G lives on. If a gateway is located atop the hill together with station G as shown in Figure 4B, then A, B, C and G all have equal access to the spacecraft. The gateway acts as a second transponder in series with the spacecraft and decouples the user interface to the spacecraft. Note that the gateway does not preclude individual access to the spacecraft by any station.

Conceptual User Equipment

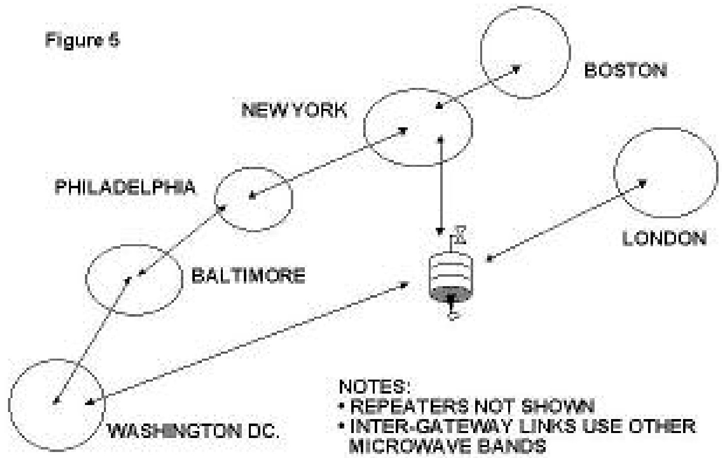
User equipment is also modular. The example discussed in this section uses 1.2 GHz as the user transmit frequency and the 2.4 GHz band as the user receive frequency. This frequency pair has been chosen because 1.2 GHz transmit is used as the Mode L uplink and 2.4 GHz is the Mode S downlink. A non rotatable microwave antenna is aimed at the gateway. This antenna may be placed on a mast, roof or balcony. Attached to it are the up/down converters which convert the gateway signals to those used by the 2 meter and 70 cm equipment in the radio shack. This gives the user Mode B in the shack and minimizes the radio frequency (rf) attenuation in the cables between the antennas and the radios. DX can be worked without towers and beams. The equipment also contains a simple self monitoring capability to allow the user to verify that the equipment is operational. The equipment can provide digital or analog communications or a mixture. Real-time video is also a possibility. Suitable low cost equipment for users at these frequencies has already been described in the literature. [7][8].



Linking Gateways.

When wide band gateways are estab-lished in urban areas, there is no reason why links should not be set up between gateways in neighboring areas, much in the same way that nodes link packet radio local area networks (LAN). A conceptual linkage along the east coast of the U.S.A is shown in Figure 5. From the user's point of view, there is no difference if the gateways are linked by terrestrial or satellite nodes. The actual inter gateway links would also use a pair of microwave bands.

Figure 5



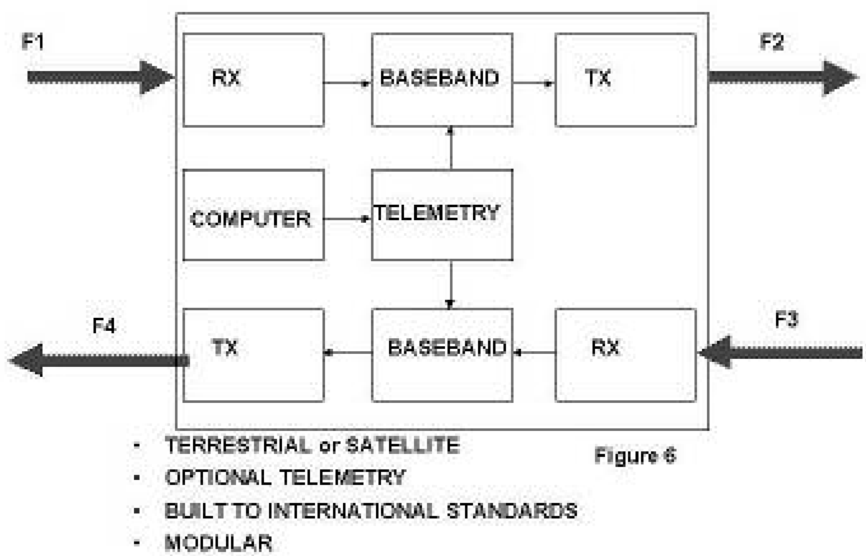
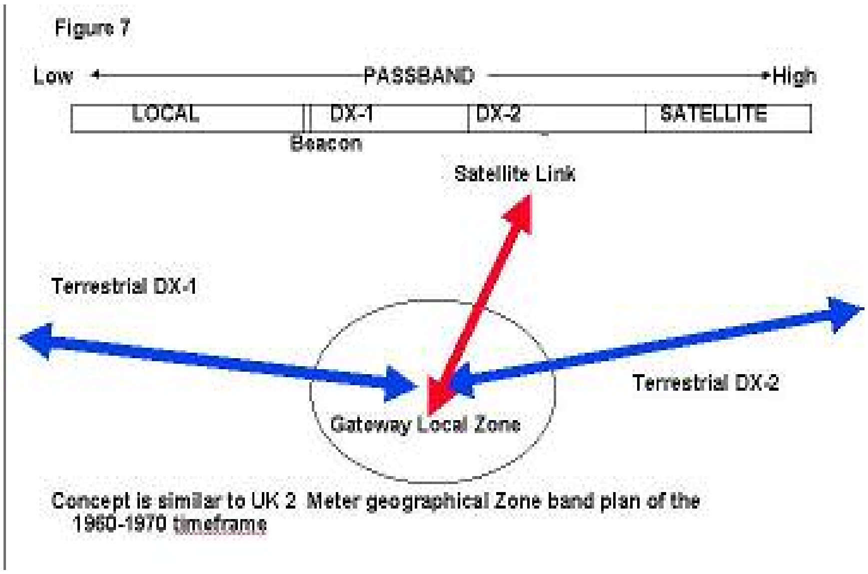


Figure 6



The conceptual gate-way link node is shown in Figure 6. It is a conventional design and uses modular construction. It is also built to standards. The same block diagram can be applied to a satellite or to a terrestrial node. One way of using linked gateways is by frequency division. This approach is similar in concept to the UK 2 meter band geographical band-plan of the 1960-70 timeframe [9]. Figure 7 illustrates the passband of a gateway with two terrestrial links and one satellite link. Users would chose which link they wish to access by transmitting in the relevant part of the passband.

Advantages of the Gateway

Gateways have several advantages, some of which are described below.

- **Gateways do not preclude individual radio amateurs from access to space-craft.**
- **Gateways provide easy user access.** Antennas can be fixed in position. User tracking problems do not exist.
- **Gateways provide controlled access to spacecraft.** The effects of high power users are only felt by the other users of the same gateway. These irate users may be able to deal with their high power users according to local customs.
- **Gateways can provide full duplex communications capacity.** This capacity is lacking from most present day amateur radio contacts.
- **Gateways allow spacecraft to be simpler.** Spacecraft will not have to contain a number of transmitters and receivers for the different modes. Users will no longer have to remember operating schedules for when particular modes will be useable.
- **Gateways allow spacecraft builders to tackle higher frequencies.** Spacecraft for amateur radio are built by volunteers for the challenge. They are interested in pioneering new techniques and new frequencies.
- **Gateways would decouple the majority of the users from these new**

frequencies. The same set of user equipment could then be used for several different spacecraft, each operating with different microwave uplinks and downlinks.

- **Ground nodes allow hands on performance measuring and tests of proposed future flight hardware.** If the difference between a terrestrial transponder and a ground transponder on a node is only the environment, several versions of proposed hardware and software can be ground tested by real users in different parts of the world before flight. Non viable designs would be discarded without incurring the cost of the launch and the embarrassment of the users finding out how unsuitable the hardware really was. On the other hand, suitable techniques that fail to become active in orbit may be demonstrated and become widely adopted on the ground.
- **Gateways provide a training ground for developing new technical talent for the radio amateur space hardware development program.** Up to now, amateur spacecraft are built to order. A launch date is obtained, and the team strives mightily to meet that date. So far they have all succeeded in that the hardware has been aboard the rocket when it lifted off. This pressure is real because rocket payloads have to be balanced. If a date is missed, the launch agency might never allow amateurs another chance, and there are very few launch agencies. The project team have to allocate the work to people whose performance capabilities are known. They cannot take a chance on an untried person, and cannot take the time to give that volunteer a chance. New volunteers are caught in a Catch-22 situation when trying to join existing teams.

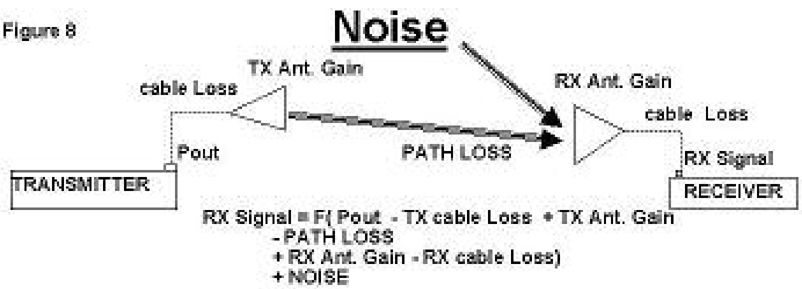
  New groups on the other hand can develop their own spacecraft, but to form a group, a particular nucleus has to exist. Ground nodes on the other hand can be built by clubs, technical schools and other starting groups. They can take the time to do it right. They don't have a tight launch date to meet.

- **Gateways can also reduce the cost of accessing satellites for the individual users.** They can use the same equip-ment they use for terrestrial QSOs for spacecraft access. In fact, gateways make the communications link trans-parent. If the terrestrial gateways get to be linked in a manner similar to the packet radio network of today, the only way users may know that they are communicating via a satellite is by the time delay on the signals.

Path Attributes

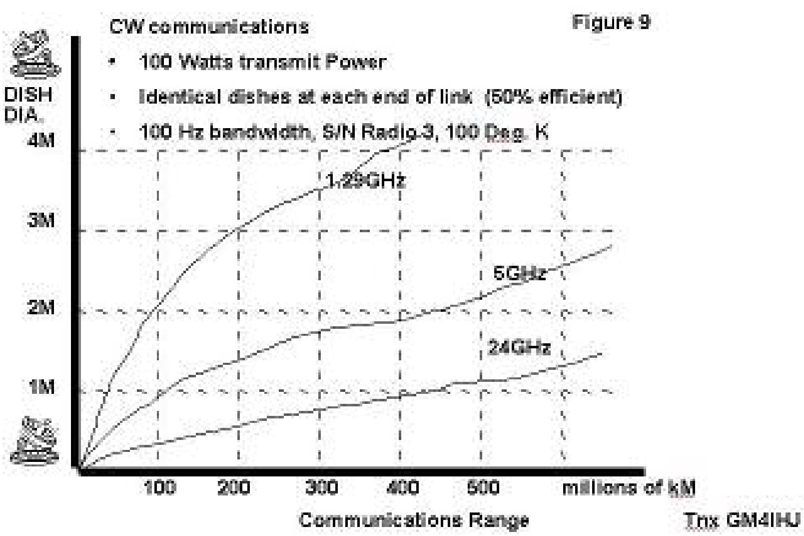
Consider the path loss and noise attributes of the microwave link. The goal of the transmitting station is to put a useable signal into the antenna socket of the distant receiver. For any given path between two stations. The received signal strength is a function of the gain of the antennas and the cable losses at each end of the link as well as the attenuation over the distance of the link. These factors have been worked out and the received signal levels at various frequencies for different link parameters can be readily predicted. **The second major factor to impact microwave communications is noise.** Atmospheric noise is both natural and man made. Most radio amateurs living in urban environments suffer from the effects of man made noise. Noise is also present in the front end of receivers. Any communications link design such as that shown in Figure 8 has to take noise into account.

Figure 8



PATH LOSS	LOSS
TERRESTRIAL	distance
UP LINK	distance
MOON BOUNCE	distance + Reflection coefficient + distance
E-M (1 Way)	distance

Adding trans-ponders or gateways in series will add noise to the link, a phenomenon which will have to be accounted for. A typical example of the communications capacity of a link using a 100 Watt morse code transmitter, with identical dish antennas at each end of the link, in a 100 Hz bandwidth is shown in Figure 9.

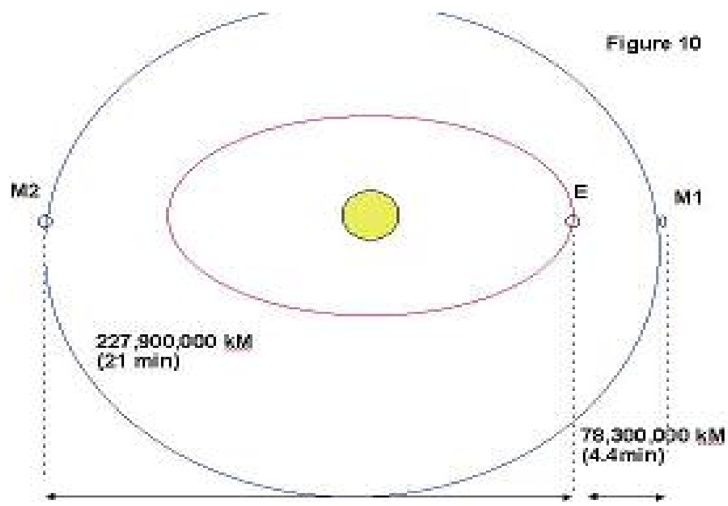


The limiting factor seems to be distance. A 1 meter dish provides com-munications capabilities out to 450,000,000 km at 24 GHz. A 2 meter dish will provide QSOs at 1.2

GHz out as far as 100,000,000 km. Given that the moon is at a mean distance of 384,399.1 km from the earth, why does moonbounce require a lot of power? Well in moonbounce, much of the power is lost at the moon because it only reflects a minuscule percentage of the incident power. The earth transmitter has to uplink sufficient power to overcome that loss and provide a signal leaving the moon that is powerful enough to overcome the return path loss. A one way link does not have to worry about what happens to the signal once it arrives at the destination providing it is strong enough to be received.

Interplanetary Communications

A range of 100,000,000 km provides communications capabilities with future bases on the moon or Mars. The distance between the Earth and Mars varies between about 80,000,000 and 230,000,000 km depending on the positions of the planets as they travel along their own orbits around the sun as shown in Figure 10.



Overcoming the path loss is only one problem that has to be faced by the radio amateur configuring for interplanetary communications. The major problem will be the time delay. The one way travel time for a signal between the Earth and Mars varies between about 4 minutes when Mars is only 80,000,000 km distant, and 20 minutes when Mars is 220,000,000 km. If you've ever listened to a pile up on 20 meters, think about what it would be like if it took up to 80 minutes or so to get an acknowledgement of the first call. Interplanetary amateur radio QSOs will not be real time voice links in the same format as intraplanetary QSOs. *Nobody ever said that a QSO had to take place in real time.* Apart from the path loss and the time delay, both planets are rotating, so there will be Doppler shift on the signals. For any station on the amateur radio station located on the surface of the Earth (earthstation), Mars will only be above the horizon for a few hours each day. There is no guarantee that when Mars is viewable by an earthstation, Mars base will be able to see the Earth let alone the same earthstation. These problems are not insurmountable, PCs can handle all the math involved, but they do tend to make direct inter-planetary communications difficult. If suitable spacecraft were in orbit about both planets they could make inter-planetary communications much easier. However, getting these spacecraft built and into suitable orbits may be difficult. The concept of direct and indirect interplanetary communication is shown in Figure 11.

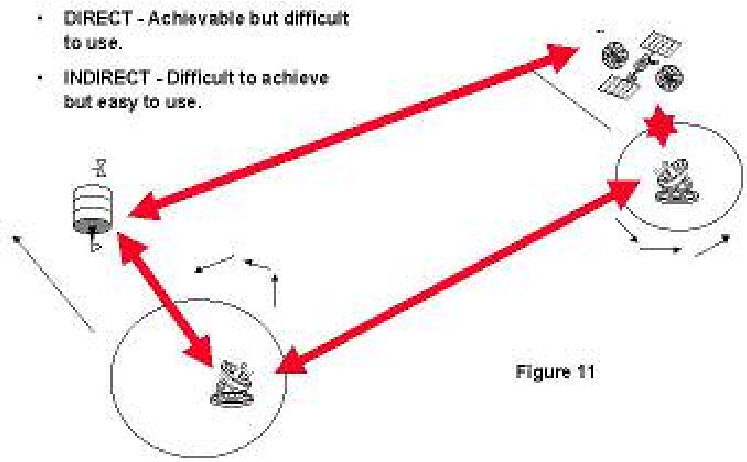


Figure 11

Perhaps, radio amateurs will need not build their interplanetary relay satellites. Amateur radio seems to be in space to stay. It is an important part of MIR daily activities [10]. It has flown on the Space Shuttle and amateur radio may even be manifested as personal equipment belonging to the astronauts. If that happens, any flight carrying an astronaut who is a radio amateur will have some amateur radio activity. Operations from the shuttle suffer from the lack of an outdoor antenna [11]. Bulkhead fittings are present on the vehicles so the only technical problem preventing the attachment of suitable antennas in the payload bay is the cost of the paperwork required to document the changes. The National Aeronautics and Space Administration (NASA) is currently planning for upgrades to the NASA Communications Network, Space Station support and the new Customer Data Operations System (CDOS). Amateur radio needs to get their inputs into the system now while it is in the planning stage. If they are in from the beginning, they are in at minimal cost. A conceptual integrated approach is shown in Figure 12.

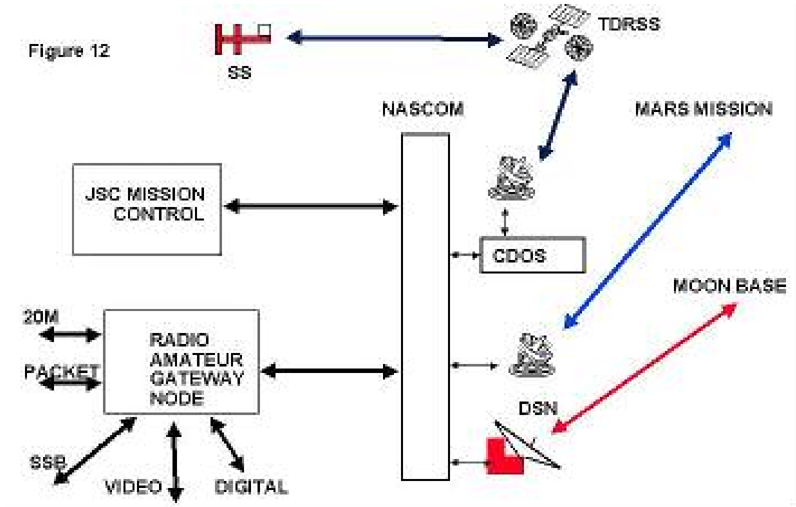


Figure 12

Summary

Gateways of the future can radically change amateur radio as we know it today. A Plan for an integrated terrestrial and satellite radio amateur communications network is a plan for the future of our microwave bands.

Gateways of the future will be full duplex to provide new capabilities to attract the communicators. They will provide both intraplanetary and interplanetary communications capability. They will provide high speed audio, video and digital com-munications. They will not inhibit individual access to the microwave bands.

Gateways of the future are feasible and can be built using 1991 technology. A well equipped high frequency (HF) packet radio Bulletin Board System (BBS) contains about $5,000 of equip-ment, a packet radio Node, about $500. Gateways should cost less than $5,000.

Gateways of the future need standards and imagination. They should be designed in a top down manner and implemented from the bottom up. Let's not repeat the haphazard implement-ation of the packet radio mess we have today by providing standards, guidance and education **up front**.

Gateways of the future provide something for everybody. Users get easy access to satellite and DX communications and a host of new services. Satellite builders get to play with higher frequencies. **Best of all, they provide a plan for the use of the microwave bands in a manner for which the bands are best suited.** Such a plan may also tend to safeguard those bands for the Amateur Radio Service.

In the past radio amateurs have acquired boxes and asked themselves the question "How can I use them ?" This paper has presented a vision of the future. Perhaps the question should be posed differently. "I have a vision of the future, how can I get the black boxes to implement the vision" ?

References

1 Robert A. Burgelman, Modesto A. Maldigve, *Strategic Management of Technology and Innovation*, Irwin, 1988.

2 Based on presentations at the Sixth AMSAT-UK Space Sym-posium, July 1991.

3 David Hull, VK3ZDH, "Report on the 1975 International AMSAT-OSCAR Experimenter's Conference", The AMSAT Newsletter, Volume 7 Number 2 June 1975.

4 Joe Kasser, W3/G3ZCZ, "The AMSAT Phase 3 Satellite", Orbit Magazine, Volume 1, Number 1, March 1980.

5 Joe Kasser, W3/G3ZCZ, "Is This the Future ?", The AMSAT News-letter, Volume 10, Number 3, September 1988.

6 Joe Kasser, "The Sky's the Limit", Byte, Volume 3, Number 1, November 1978.

7 Ed Krome, KA9LNV, "Mode S: Plug and Play", The AMSAT Journal, Volume 14, Number 1, January 1991.

8 Freddy de Guchteneire, ON6UG, "Preparing for 10 GHz Satellite Communication", Proceedings of the Sixth AMSAT-UK Satellite Symposium, July 1991.

9 Jack Hum, G5UM, "Four Meters and Down :- VHF and UHF Band Planning for the Seventies", Radio Communications, Volume 45, Number 10, October 1969.

10 Joe Kasser, G3ZCZ & Valery Kondratto, UV3DQE, "CQ Earth, This is MIR Calling", The AMSAT Journal, Volume 13, Number 2, May 1990.

11 Ron Parise, WA4SIR, "Shuttle Amateur Radio Experiment (SAREX)", The AMSAT Journal, Volume 14, Number 2, March 1991.

Glossary

AMSAT	The Radio Amateur Satellite Corporation
AO	AMSAT-OSCAR
BBS	Bulletin Board System
CDOS	Customer Data Operations System
DX	Distant transmission
HF	High Frequency (Short waves)
LAN	local area network
NASA	National Aeronautics and Space Administration
OSCAR	Orbiting Satellite Carrying Amateur

	Radio
QSO	Contact between two radio amateur stations
rf	radio frequency
uhf	ultra high frequency
vhf	very high frequency