APRS GENERIC DIGIPEATING SATELLITES for HT and MOBILE Satellite Communications

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It's time for mobile and handheld amateur satellite communications and we can do it easily. Proposals for amateur satellite constellations have been made in the past, but they assume a coordinated effort. Such an effort is unrealistic in the catch-as-catch-can amateur environment. This paper suggests that the future growth of amateur satellites can in fact accommodate uncoordinated growth and still provide synergistic advantages to mobile and handheld operations. There are several factors driving this concept making it easier, cheaper and more viable:

- Launches are plentiful, many free rides exist
- Electronics can be smaller than a softball
- The link from a handheld can be done with 1 watt
- Dual band HT's are plentiful
- One HT has a built-in 1200/9600 TNC and kbrd/display
- Mobiles are a convenient time to operate for many
- Travelers need satellite comms in remote areas
- HT/mobiles need little coax, no preamps, nor complex antennas
- Mobiles/Handhelds provide a common user configuration
- HT/omni downlinks are ideal for school demonstrations
- Many Schools want to build satellites for education
- Amateur Satellites should not compete with the free bandwidth of the internet for fixed stations. We should concentrate some of our satellite bandwidth on amateur communications for mobiles and handhelds.

In the past, HAMS were the driving force behind each of our satellites wanting to do something new and different and better for HAM radio. More bandwidth, higher speeds, new digital tecniques, longer ranges. The justification for a new experiment provided the rationale for the project. With that mindset, there were lots of new things to tinker with but little support or peer justification for flying just another one-of-the-same.

The current climate is quite different. Universities want to build satellites for the education of their aerospace students. There are at least a dozen such satellites currently under construction. In this case it is the "design and building" that are the main educational drivers. This means some of these projects are actually looking for a mission, or an excuse to build a satellite. These satellites become "amateur" satellites simply because the spectrum is easy to get. We, "the AMSAT community" should provide guidance so that we get what we want and need for the future of amateur radio while these programs with deep pockets get the educational experience they need.

THE GENERAL MISSION AND BUILDERS CHANNEL:

What we need is a published General Mission requirement and a Builders Channel. This will encourage builders to consider the inclusion of a general purpose FM or digital transponder on a common channel. The resulting simple transponders would all be similar and provide the amateur community with a fleet of general purpose relays for mobile and handheld communications while providing builders with a persistent mission requirement. Actually there are three missions and three builders channels, one for FM voice, one for brief 1200 baud digital position/status/message uplinks and one for bulk downlink of all amateur traffic using the very effecient PACSAT protocol at 9600 baud.

Focusing builders-in-search-of-a-misson on this General Mission and Builders Channel with only one power-class of users (mobiles and HTs) will make much more effecient use of our precious spectrum and also keep the remaining spectrum available for other analog, wide band and experimental modes.

HT and MOBILE STATION CLASS:

Even though HT's and mobiles differ in power by 10 dB (5 versus 50 watts), they are comparable in most respects. The downlink is identical. Both use omni receive antennas with no cable loss. The uplink is also quite comparable. HT's can easily vary their orientation and polarity and/or use small

The popularity of AO-27 is matched only by its own congestion. Imagine, however, if there were 12 other AO-27's on the same frequency giving two passes per hour round the clock *AND* a change in operating habits to let everyone have a chance. Photo by Phillip Fortenberry N5PF at last years AMSAT Conference

handheld gain antennas. The mobile is usually stuck with a vertical which has a null overhead and a good chance of being in the wrong polarity half the time. Thus the mobile's SO watts is, on average, quite comparable to the handheld's **5** watts., So, for the purpose of this paper, mobiles and handhelds are considered in the same power class. By having such a well defined user station baseline, it is easy to design a Handheld/Mobile mission for amateur satellites and to make good decisions about their operation on only a minimum set of builders channels as shown below.

BUILDERS CHANNELS:

The following builders channels are recomended for both digital and voice:

2m	FM VOICE:	FM downlink to HT's and mobiles
2m	1200 Baud:	UI packet channel to HT's and mobiles
2m	9600 Baud:	Pacsat protocol message server channel
70cm	FM Voice:	FMuplink from HT's and Mobiles
70cm	1200 Baud:	Alternate uplink from digital mobiles
70cm	9600 Baud:	Uplink for 9600 baud Message Servers

These are single channels to be shared by any number of satellites built by anyone who wants to. The actual practical number is probably about a dozen or so since orbits with free rides will be random and we want to minimize overlaps. Actually, this is not a limitation as many of these payloads may be launched by the shuttle and other missions enroute to ISS and so will have life times on the order of a year or less. Brief periods of overlapping coverage will have minimum impact due to the 10 dB range variance, many dB of antenna pattern variance of both the satellite and users, and the 10 dB or so FM capture effect.

PACSAT MESSAGE CHANNEL:

Notice the provision for a 9600 baud Pacsat protocol downlink on 2m. This single channel with many birds has the potential to deliver to every ham on the planet with an HT, over 300k per pass per satellite. Or with 10 satellites in orbit, over 10 megabytes of personal messages and daily amateur radio news to everyone! This is where everyone monitors for their traffic. The 2 meter downlink is 9 dB better than any of the existing PACSAT **70** cm downlinks using the same power. Thus, easy to do with 1 watt microsats to HT's with rubber ducks. The channel also listens briefly for acks.

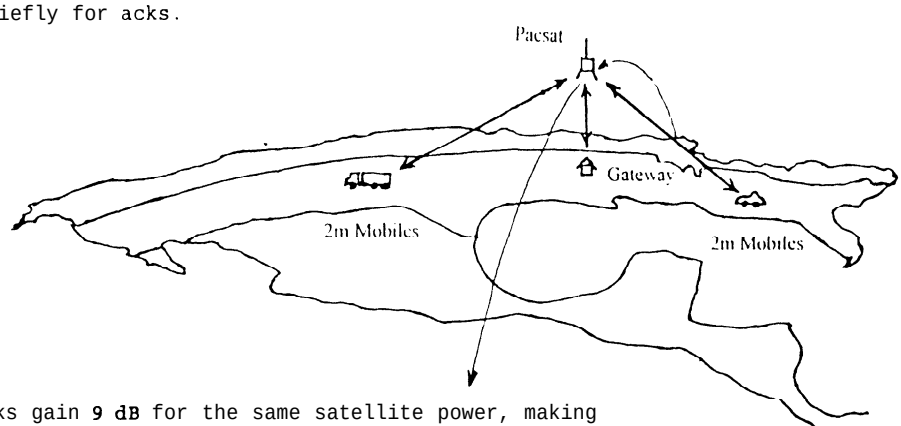
The objective of this channel is not to replace the existing PACSAT store-and-forward message/file systems, but to augment them for the downlink distribution of smaller real-time messages to all users usually in receive only mode. At 9600 baud, that is a tremendous asset for amateur radio. By using **2** meters, the lower path loss means that stations need not track the satellite. Just leave their packet capable HT on the 9600 baud channel and it will receive the traffic whenever a bird flies over even if they are in receive only mode.

Further, this PACSAT protocol downlink can be REGION specific by not putting the file system on orbit, but on the ground! The 9600 baud channel simply operates in bent-pipe mode for major internet linked file servers on the ground. Thus when over the USA, the channel is full of traffic for USA mobiles While it is over Europe, the bird is supplying all European traffic. Thus, the channel can be optimized for each region. This greatly multiplies overall worldwide capacity.

Since each satellite is only serving as the on-orbit digipeater for regional message servers, each satellite is generic. which ever one is in view at any time serves to deliver the messages to all mobile handhelds within 1500 miles. The Regional Message Server ground station continuously transmits a stream of all message traffic. New messages are initially repeated more often than older messages on a decaying schedule. For example:

New messages	are repeated	every 2 minutes
After 30 minutes	every	3 minutes
After 60 minutes	every	4 minutes
After 2 hours	every	5 minutes
After 4 hours	every	6 minutes
After 8 hours	every	7 minutes
After **16** hours	every	8 minutes
After 24 Hours	every	9 minutes

Thus, at 9600 baud and an average message length of 1K, over 500 messages per pass per satellite can be delivered. Yes, it makes the satellite less valuable over the oceans and most of the 3rd world, but those areas are aptly covered by the existing Pacsats that cannot deliver traffic to handhelds.



PACSATS with 2m downlinks gain **9 dB** for the same satellite power, making handheld and mobile receiption very easy to omni antennas. **Message** delivery to/from anyone anywhere with an HT is possible.

The **Kenwood** THD7 HT can be a handheld satellite trasnceiver with buit-in 1200 and 9600 baud **TNC's** combined with keyboard and displays for position/status reporting and short messaging.

DIGITAL MISSION:

Just like the many worldwide commercial satellite pagers and hand-held phones, Amateur radio now has its own "satellite handheld" in the **Kenwood** TH-D7. Just one packet can contain everything you need to know about a station and it takes less than 0.3 seconds per station. This means that 10 times more users per pass will be able to participate on the digital transponder as on the voice channel! In addition, the digital packets containing the stations position and status and messages can be interlinked into the worldwide APRServe **internet** backbone allowing worldwide communications between these handheld users anywhere to anywhere.

The digital mission using hand-held to handheld communications was recently demonstrated in an impromptu test during the first week in early June when more than 55 HT users easily communicated over 500 UI packets among 160 stations via the MIR digipeater. [ ] The presence of thousands of these shirt-pocket digital satellite communicators is an opportunity that should not be overlooked! Even conventional **HT's** can transmit APRS type position/status using only the match-box sized APRS Mic-Lite Mic-Encoder plugged into the mic jack.

The popularity and functionality of brief APRS UI type communications has been well dsmonstrated and is beyond the scope of this article. Readers can view the worldwide APRServe system live via TELNET to 199.227.86.221 port 23 at any time or check station positions via www.aprs.net. This system provides terrestrial HT coverage to over 90% of the US amateur population. (But less than 20% of the land mass and none of the oceans nor most foreign countries and Europe. Hence, the need to extend links via the digital builders channel).

FREQUENCIES:

One of the reasons for this builders channel concept is to make more **effecient** use of our existing spectrum and to allow for more orderly growth in the amateur satellite realm. There are many considerations in effectively designing a satellite link. First, 2 meters is, by an order of magnitude, the easiest band for handhelds, because the link budget is 9 **dB** easier and the doppler is negligible for existing FM radios. Conversly 70 cm has over 16 KHz of doppler and requires 9 times more power for the same performance. Thus, 70cm up and 2m **downlink** has the following advantages:

- 9 **dB** less power required on the **satelite** power system
- Omni spacecraft antennas require no attitude control
- No doppler tracking of downllnk by users
- Compatible with all FM amateur radio equipment.
- Compatible with handheld TH-D7 packet HT

The UHF disadvantages are mitigated on the uplink as folllows:

- Ground users can use more power, or gain antennas
- User can compensate for doppler OR
- **Satelite** receiver can have AFC OR
- Satellite can use a **wideband** IF to minimize doppler

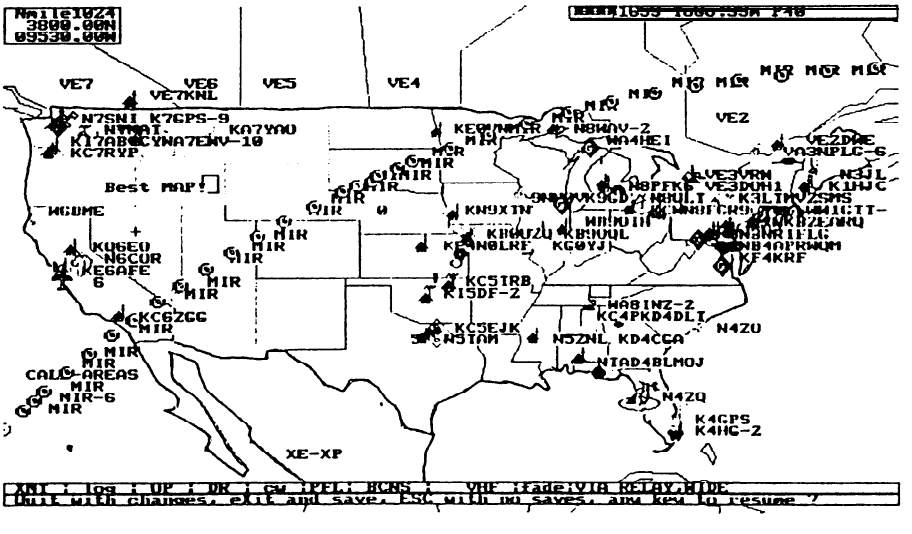
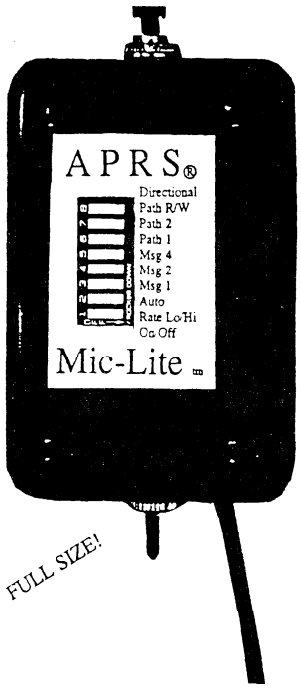


Figure . This is an APRS screen capture after the third pass of MIR during the special APRS-MIR tests conducted on I 1 March 1998. It demonstrated the potential of using an amateur satellite digipeater for relaying mobile position/status/messages.

The only downside of this arrangement is the difficulty on the Voice birds of filtering to avoid 3rd harmonic desense of the satellite UHF receiver by its 2 meter downlink. On the 2m 1200 baud digital channel, HT-to-HT operations will usually use the satellite as a single channel digipeater for UI frames thus providing the 9 dB and zero-doppler advantages to everyone with an HT as was demonstrated via MIR. Simplex digipeating is required since the thousands of satellite packet capable HT's contain TNC's that can only operate on one band at a time. To help spread out the uplink load, the mobiles with 10 dB more power can transmit on 70cm, where the satellite can use AFC or a wideband receiver to mitigate a problem of high doppler.

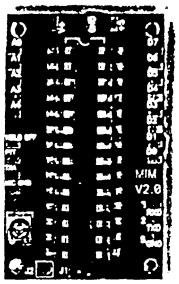
Combining both uplink and downlink for the HT's on one channel is fortunately not a problem for the UI (APRS) application because dozens of ground stations are all linked by the internet. Thus only one ground station needs to receive the packet error free and it is distributed worldwide. Only 5 such ground stations would have a 99.99% chance of at least one of them hearing each packet and delivering it error free to the network even if their channel was more than 30% busy with local traffic.

In conclusion, I believe that establishing Builders Channels and, published Common Mission Objectives for mobile/HT worldwide satellite communications could greatly benefit the Amateur Satellite community. . would provide a mission target for schools, a much improved use of or sparse satellite bandwidth on 2 meters; and a constant source of satellites for a constellation of mobile communications amateur satellites. Further it defines a consistent user station class and power level for equal access by all, and promotes shorter practical protocols to allow more users brief access.



FULL SIZE!

The **MIM/Mic-**Lite module can be built into most Microphone enclosures or installed into a mini box to permit APRS **osition/** status reporting from any HT.



FULL SIZE!

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APRS MIM Module

Complete APRS Packet TNC transmit module. Transmits Position, BText Telemetry at user specified rate.

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