PSK-31 Linear/FM Satellite Transponder

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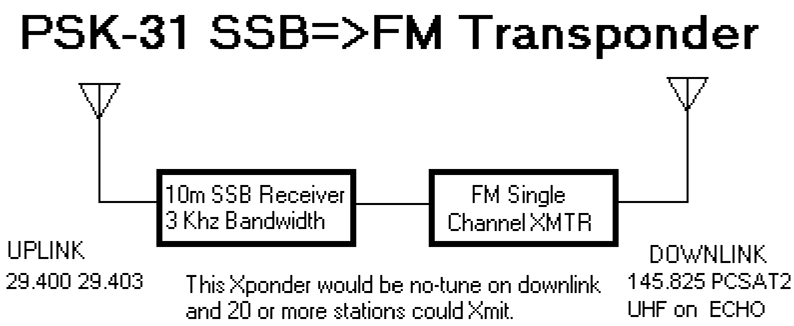
With the sweeping popularity of PSK-31 as a very narrowband and weak signal digital communications mechanism requiring only a PC sound card and radio, there is great potential to use PSK-31 as a low cost easy-entry satellite application. In only 3 KHz of bandwidth, as many as 20 or more simultaneous users can be accommodated. Usually, the same advantage of the very narrow bandwidth that makes this possible also tends to make normal operation via satellites impossible due to very high Doppler shifts. But the following idea solves that problem. It evolved from many ideas we explored with Peter Martinez back in 2000 while looking for ways to use PSK-31 via satellite. See the Paper. As this idea matured, we solicited Mirek Kasal to build the Flight Receiver



ADVANTAGES OF THE 10m Linear Uplink => FM Downlink

- No downlink Doppler (other than crude FM 5 KHz steps)
- All users remain in same relative position in analog passband
- Stations accommodate Uplink Doppler to fit in common analog Passband
- Downlink FM transmitter can be on 2m/70cm band with minimal Doppler issue
- No requirement for Linearity on Downlink Transmitter
- Downside is higher power budget and full power even if 1 user.
- Each user can adjust Uplink power for equal audio level in downlink
- Easy reception with any FM scanner
- Uplink Geometry on 10m band almost guarantees equal user signal levels

DOPPLER Expected

The Doppler on the 10m band is about 15 times less than on 70 cm and changes at a rate between about 1 to 5 Hz per second. The following table is a worst case (350 km orbit) and it shows the rate of change of Doppler for typical passes below the peak elevations shown.

50deg	40deg	30deg	20deg	10deg	Peak Elevation of Pass
4%	8%	16%	33%	67%	Percentage of total passes above this angle
0.1	0.2	0.3	0.7	1.2	Doppler change in Hz per second
0.3	0.5	0.7	1.1	1.9	
1.0	1.3	1.5	2.4	2.5	
3.5	3.8	4.0	4.1	3.0	
9.0	7.3	6.5	5.0	3.0	(Peter computes absolute worst case is 16 Hz/Sec)
6.0	5.5	5.0	3.5	2.5	
1.9	3.6	2.1	3.0	2.3	
0.5	0.9	0.9	2.0	1.5	
0.1	0.2	0.3	0.9	0.9	

So 2/3rds of the time the Doppler rate of change is in the range of about 3 Hz per second or less. It looks like 90% of the time it is 5 Hz or less. And worst case is 16 Hz change per second. Peter G3PLX is working on a second order AFC tracking loop to keep up with this dynamic rate of change. But it will be better if all users correct their Doppler in their uplink instead of the downlink. Notice also that for LEO spacecraft the Doppler rate of change is always downward. For AO-40 in an elliptical orbit, however, the rate of change can be either direction depending on whether the satellite is accelerating towards you coming in from Apogee, or slowing down as it goes outward from Perogee.

Actually, for software written for this application, it is best if the software adjusts for this Doppler on the Uplink so that the relative position of everyone in the passband will remain constant. This should be easy to do, however, because the Satellite is full duplex, so your sound card can be monitoring your signal on the downlink and making AFC changes on the uplink to keep you at the same frequency on the downlink…

CONCEPT OF FULL DUPLEX PSK-31 OPERATIONS:

Because the software will be working FULL DUPLEX so that it can listen to its own Doppler shifted uplink in the downlink to run its AFC, this means that the user will typically operate KEY DOWN on 10m the whole 8 minute pass. But while he is transmitting, he will be SEEING everyone else on the band. Thus this will be a new mode of PSK-31 operations, kind of like a chat room full of people with everyone seeing what everyone is saying in real time and being able to KEYBOARD to them all as fast as one can type. Each pass will all be over in 8 minutes or less, though.

The ideal downlink band is on 2 meters where the Doppler is less than +/- 3 KHz so NO downlink tuning is necessary if the deviation on the transmitter remains below about 3 KHz deviation. But if the 70 cm Amateur Satellite Downlink is required, then the operator will have to change the frequency of his UHF FM receiver 3 or 4 times a pass to keep up with the +/- 9 KHz of total FM carrier Doppler on the downlink.

PASSBAND POWER SHARING:

One of the biggest problems with linear transponders is power sharing of power in the linear passband. This results in the strongest signal getting most of the power at the expense of the other operators. This is compounded when the AGC reduces the overall passband gain to prevent the strongest signal from overloading the system, which results in everyone losing power.

One of the greatest advantages of this 10 meter PSK-31 Transponder is the inherent self leveling of uplink power in the passband as enumerated in the following diagram:

10m Uplink Multi-User Signal Balance

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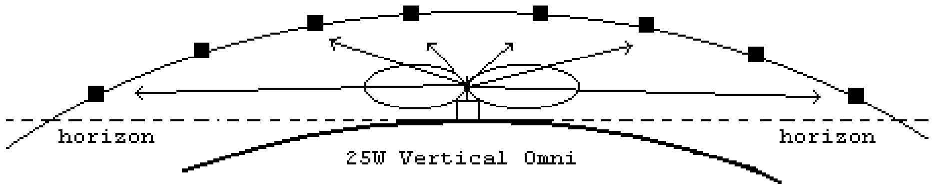

The elevation gain pattern for a vertical 10m Omni antenna is almost perfectly inversely proportional to satellite range. This yields an almost constant received user uplink power regardless of individual user geometry. Further, the convenience of an omni versus the cumbersome size of any steerable gain antenna on the 10m band will help assure most users will adhere to this uplink configuration and ERP.

Thus, this PSK-31 transponder will have four significant power balancing factors never seen before in a multi-user shared-power transponder:

1) Link budget supporting omni vertical antenna.
2) Great simplicity of omni vertical and dis-incentive for beams.
3) Antenna gain inversely proportional to range, mitigating geometry.
4) Common 25 W commercial transceiver (and no readily available legal power amplifiers in this band)
5) Constant power PSK uplinks give constant passband loading

USER LICENSE REQUIREMENTS:

Another unique aspect of this transponder is that it will be the first amateur satellite to use 10 meters as the uplink band. As noted above, all of the advantages of this PSK-31 low-doppler and balanced passband design depend on the use of 10m as the uplink band. Unfortunately, the ARRL (and probably other countries) band plans suggest only 29.300 to 29.510 for “Satellite Downlinks”. This apparent limitation of 10m for only downlinks is only a legacy of the early Mode A satellites and is not part of the FCC nor the ITU rules. The entire 10m band is legal from that perspective. A second issue is that only the 28.1 to 28.3 MHz sub band is authorized for Novice and Tech-Plus licensees in the USA.

Therefore, we originally proposed that this PSK-31 Satellite UPLINK be a 3 KHz wide spectrum somewhere in the 28.1 to 28.3 MHz CW/Digital sub-band not only so that Novice and Tech-Plus operators may use it, but also, to prevent the obvious temptation for an SSB user to saturate the entire passband with his single Voice QSO. Currently PSK-31 QSO’s on the 10m band congregate near 28.120 and a Transceiver Kit crystal controlled on that frequency is readily available from Small Wonder Labs making this an easy satellite for students to access. But since I could not resolve all the complaints from this proposal, we ended up choosing 29.400 MHz as the uplink until future designs.

In the future, I would like to proceed with the Frequency Coordination process to request an assignment of 28.117 to 28.120 MHz CW/Digital band for such a PSK-31 satellite uplink. This seems like a good choice since it is immediately adjacent to the 28.120 to 28.1235 PSK-31 segment and can be easiliy tuned by the crystal controlled PSK-31 Transcevier kits readily available. See the Band Plan

Send comments to WB4APR@amsat.org.