External ISS Communications Experiment

21 Mar 2002, WB4APR

- Joint NASA/USNA (Naval Academy(DOD) experiment
- An external autonomous satellite communications payload attached to the international space station exterior structure (EX-COM).
- The primary mission is education and outreach to schools, and youth everywhere.
- To maximize the outreach potential, the plan features the most popular communications modes, the use of simple and inexpensive available user equipment, and the best bands for maximum link budget and optimum frequency usage.

EX-COM Operating Modes

- The most popular modes permit two-way live communications between individuals.
- Although the ISS crew is the ideal participant, their participation is not required.
- EX-COM should use modes that best facilitate communications between schools and participants on the ground:
- FM voice repeater (plus crew communications)
- Packet radio UI Digipeater (50 stns /pass)
- SSTV repeater and camera (single channel)
- Wideband SSB transponder (10 nets)
- Multi-user PSK-31 (30 simultaneous users)

New Paradigm: Sound Cards and Laptops

- Since the first SAREX, MIREX and ISS missions in the mid 80's, the most significant change in technology has been the ubiquitous laptop and the elimination of all hardware modems in favor of sound card software modems.
- Thus any of the above modes can be received with any existing receiver, a laptop and the right software on an HT with whip antenna.

FM Voice Repeater

- Repeater can be used by schools or other users
- Can greatly facilitate communications of the crew.
- During crew to ground communications, the full duplex channel solves the classic hidden-transmitter congestion problems on the uplink.
- Full duplex allows all users within the footprint to hear both sides of the conversation including the uplink congestion and to thereby avoid interference.
- The repeater also lets the crew use a simple HT from anywhere in the ISS station rather than only from a fixed operating position.

Packet UI Digipeater

- A UI digipeater continues the existing capability of the ISS packet system.
- The design more than quadruples the throughput by having two or more user uplink receivers and by being full duplex.
- The system permits ISS bulletins, and payload telemetry as well as supporting user packet relay.
- It also provides system command and control.

SSTV Repeater and Camera

- The SSTV system would support three sources of image data; A camera, stored files, and user uplinked live images.
- Its downlink will use the previously coordinated 144.49 and 145.200 frequencies in ITU regions 1,2 and 3 if not in use by the crew.
- Simple software configured from the ground will manage the frequency changes.

PSK-31 Transponder

- A wideband multiuser(20+) linear mode (3 KHz).
- This novel PSK-31 concept takes advantage of the very low Doppler on 10 meter uplinks.
- Eliminates all downlink Doppler by downlinking the 3 KHz passband on a single FM 2m downlink.
- Readily available inexpensive 10m SSB user uplinks with 25W omni antennas, and typical pass geometry, levels the uplink dynamic range of users to within about 10db of each other.
- This novel PSK-31 transponder solves 3 of the primary problems of wideband transponders which are accessibility, power sharing, and Doppler.

Wideband SSB Transponder

- This optional payload would be a 30 KHz wide uplink 10m linear SSB receiver feeding a 2 meter linear downlink.
- This could support up to 10 simultaneous nets.
- This downlink can be 1 Watt to help with the power budget.
- Users need beams on the ground

RECEIVERS/ANTENNAS and BANDS:

- The objective of the downlink must be to reach simple receivers with omni antennas.
- This fundamental objective demands the use of the 2 meter band for downlinks due to the 9 dB link budget advantage and resulting up/downlink balance** to a typical user ground station.
- The viability, popularity and strength of 2m downlinks (mode B) has been clearly shown with SAREX, MIR, ISS, SUNSAT and PCSAT.
- Everyone could hear them on an omni antenna or handheld radio. **MODE-B WORKS!**

UHF Downlinks Won't Work

- Mode-j UHF downlinks require either 10 db higher power on the satellite or high gain directional and tracking antennas on the ground for the same satellite transmit power (5w or so)
- Most newcomers have never heard Mode-J because of the hundreds of dollars in gain antennas, AZ/EL tracking systems, and expensive unique modems required.
- Inaccessibility is not the approach that an ISS outreach experiment should take.
- The payload will be external, and very power limited.
- Its fixed location and attitude severely constrain the ability to optimize solar power collection.
- Thus, downlink power of any transponder will be limited to the low-power (<5W) class.

Mode-B works Beautifully

- Therefore the use of omni directional antennas on the ISS and by users on the ground combined with 2 meter downlinks and user UHF uplinks provides a balanced link system for all users.
- This is in contrast to the many Mode-J satellites (2m up and UHF down) that have a 20+ dB imbalance** in the user uplink and downlink.
- This 100-to-1 imbalance should be avoided on the ISS payload.
- The next slides detail the advantages of the balanced 2m downlink and uhf/10m uplink plan.

Footnote: Link Budget Imbalance

The 20 dB Mode-J imbalance between omni antennas results from:

- The satellite's 4W downlinks are typically 11 dB less than the users 50W uplinks.
- The downlinks suffer the added 9dB greater path loss to an omni antenna for a total imbalance of 20 dB!.
- Using Mode-B, however, results in balanced links because the 4W downlink on 2m has a 9 dB path advantage to almost equal the 50W user uplink on UHF.

2m DOWNLINK ADVANTAGES:

- The best link budget (+9dB over UHF) to an OMNI receiver for limited ISS power.
- ISS Xmtrs can be 9dB less for same link budget as UHF
- 5W class 2m transmitters have worked well on ISS, MIR, SUNSAT, and PCsat.
- Downlink is not affected by worldwide interlopers on the 2m band (taxi's etc)
- Strong presence on 2m downlinks may even help drive the interlopers away...
- Users need make no adjustment for downlink Doppler
- PSK-31 bulk FM downlink can be heard with zero downlink Doppler
- Wideband transponder Doppler is 1/3rd that for UHF

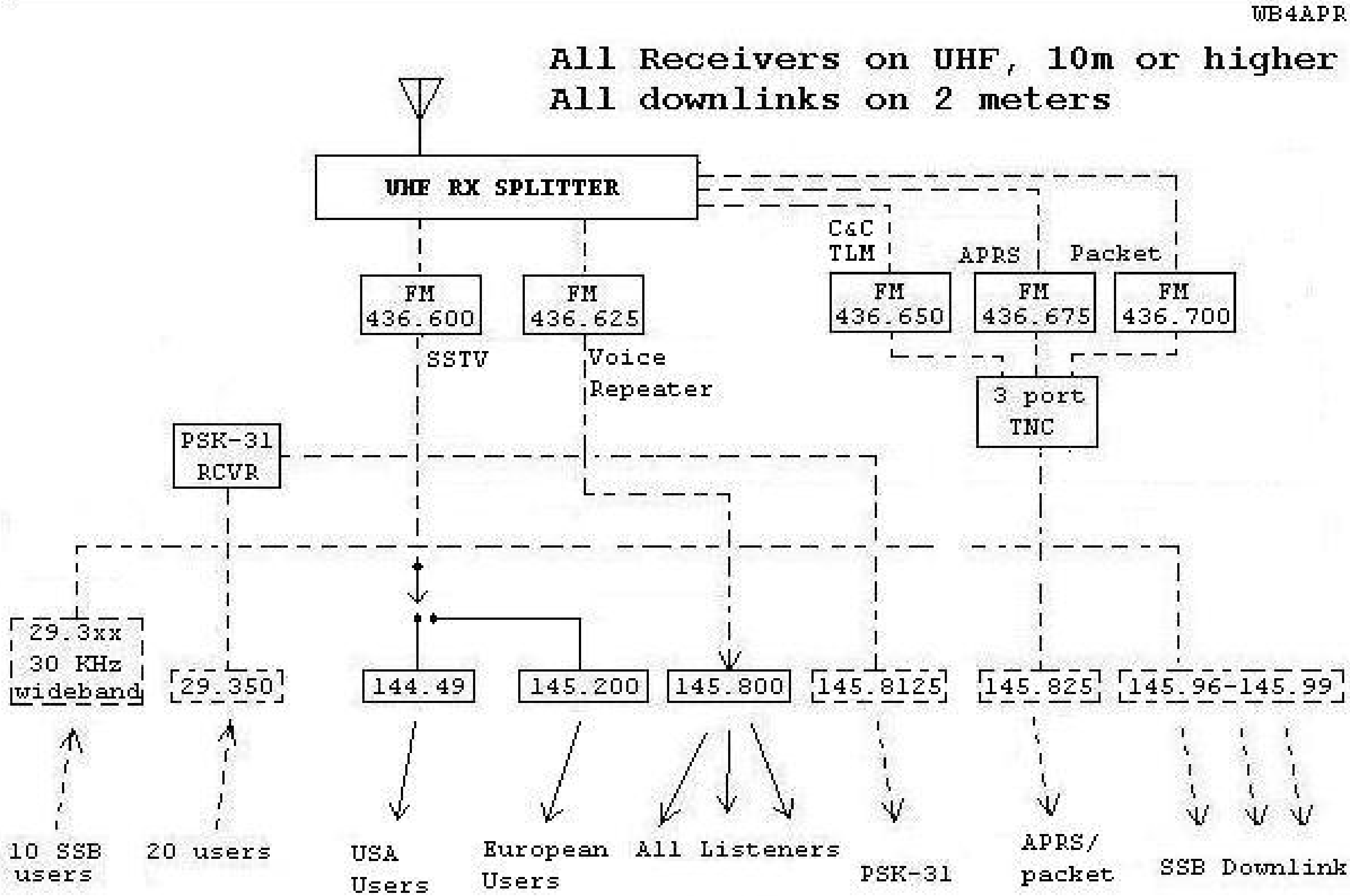
UHF UPLINK Advantages:

- Wideband (40 kHz) UHF uplink receivers on ISS allow user uplink without Doppler
- The UHF omni antenna 9 dB uplink penalty is made up with 50W user power
- Ground interloper signals down by 9 dB compared to 2m due to link budget
- Ground interloper signals down by 3 or more dB due to antenna patterns
- Requires attention to UHF receiver design to avoid 3rd harmonic desense

10 Meter Uplink Advantages:

- PSK-31 multi-user (up to 20 or more) with only 600 Hz total uplink Doppler
- May use $150 all-mode 25 watt 10M transceivers. (Versus $1000 on other bands)
- Wideband transponder using same $150 25W class uplinks levels the uplink playing field.
- Everyone uses vertical Omni's and 25 watts for nearly equal uplink ERP.
- User omni vertical antenna pattern balances close-in path gain also for user balance.
- 2006 launch coincides with solar minimum when 10m band is otherwise useless.

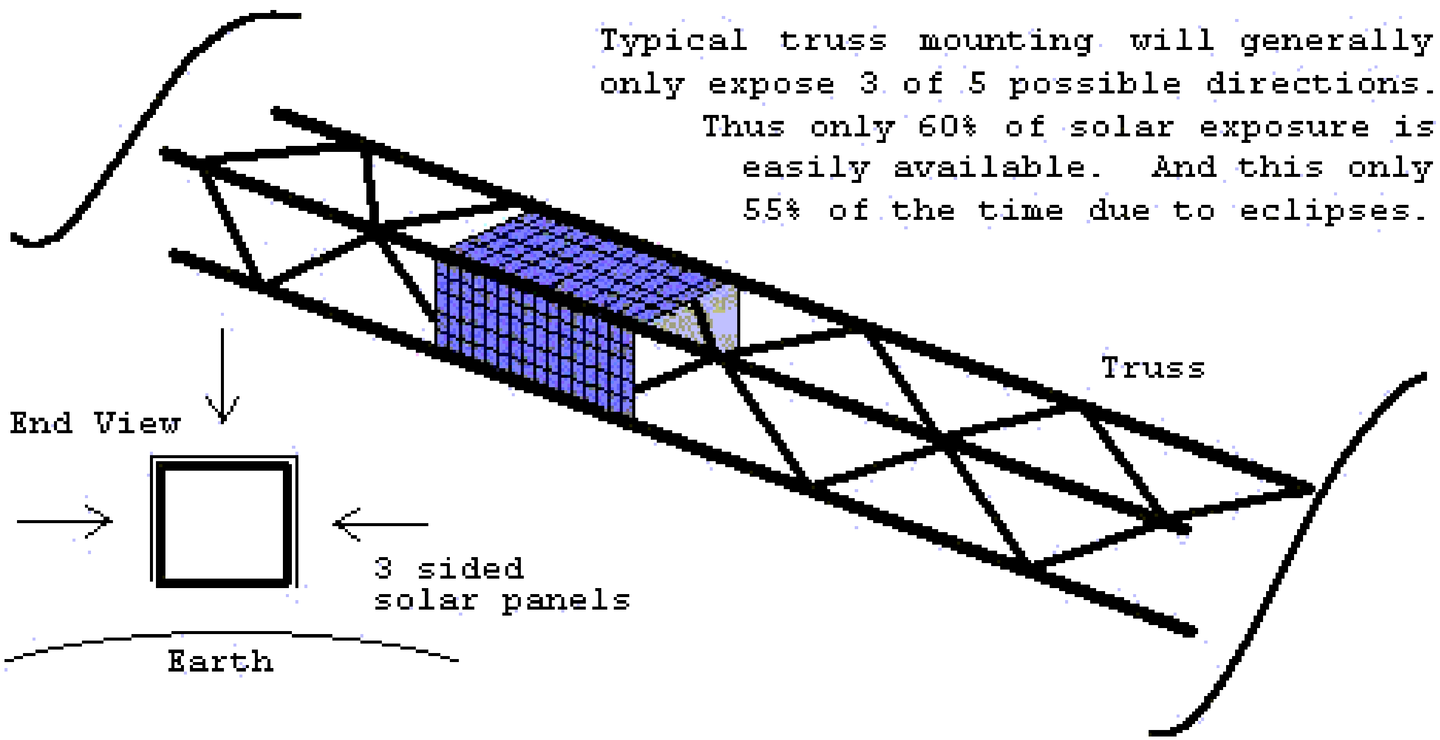
External ISS Communications Payload



Solar Power Budget:

- As a fixed external autonomous payload, solar power will be very limited.
- Mounting along a linear part of the ISS truss, even an optimistic placement of solar panels only faces three directions.
- 3 directions (3 of 5) yields only 60% power.
- Low altitude of ISS yields 45% eclipses.
- Multiple chances for structure shadowing 30%?
- Combined these limit total orbit power budget to less than 7% of installed peak array power.
- For 1 sq-m total installed orthogonal arrays (three 1/3rd sq-m panels), the average whole-orbit power available would be only about 12W.

Truss Mounting Solar Power Limits



With about 1 square meter of solar cells on three panels the whole orbit average power available will only be about 12 watts. But low worldwide user demand duty cycles will permit peak payload demands of 80W over high user population areas.

User Demand Load:

- ISS in range of users only 10% of the time.
- Transmitter power budget is only about 10%
- Receivers can use power-saving duty cycles.
- Total average user load duty cycle including inefficiencies is on the order of only 15%.
- The 12W average solar power budget could support a combined communications payload peak power on the order of 80 watts.
- Alternatively, power can be managed over a wide range by restricting operations to “daytime” hours only in some cases and still fit well within the school and educational outreach mission objectives.

Equipment Power Budget:

SYSTEM	FIXD	TX-RF	duty	Effcy	TX-DC	total
Voice repeater	1W	5W	100%	33%	15W	16W
Packet Digipeater	2W	5W	40%	33%	6W	8W
SSTV repeater	1W	5W	70%	33%	10W	11W
PSK-31 repeater	1W	5W	100%	33%	15W	16W
Wideband Xponder	1W	2W	80%	33%	8W	9W
Control system	1W					1W
Reg/distriubtion				70%		7W
Charging losses			45%	70%		12W

Total						80w

Conclusion:

- The mode-B frequencies are only representative and would require IARU coordination.
- While the EX-COM is in operation, it would replace the existing ARISS downlink on 145.800.
- At any time, the crew may disable the EX-COM and operate the existing ARISS system.
- Since they both share the 145.800 downlink, ground users will always be aware of what mode is currently active by monitoring the channel.
- From an engineering standpoint, mode B is the only viable option to meet the mission intent within the limitations of the opportunity.
- Mode-B has been solidly proven as the most popular and strongest downlink (ISS, MIR, SAREX) possible for simple stations.