Working the EasySats

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Working the EasySats

Maybe you've heard that satellite communication requires a huge investment in exotic equipment. Not so! Chances are you have everything you need to work a satellite *right now*!

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Hams love technology. The more high-tech it is, the more we love it. We're particularly awestruck by space technology. Don't you still watch the space shuttle launches on television? I never miss a launch—even if I have to videotape it and watch it after the fact. My skin still tingles when the engines ignite and the shuttle roars off the pad on a majestic pillar of fire. Without a doubt, a shuttle liftoff is poetry in motion. (If space station *Freedom* is ever built, I think all space shuttles should be required to play the "Blue Danube" waltz during docking maneuvers in honor of *2001: A Space Odyssey*!)

The only problem with space technology from an Amateur Radio point of view is that we automatically equate an expensive spacecraft with an equally expensive ground station. Before I realized how easy it was to work amateur satellites, I developed a formula to calculate the financial and psychological costs of assembling a proper ground station:

$$GC = \left[\frac{A_s}{MP}\right] C^3$$

where

GC = Ground station cost
A_s = Spousal aggravation (measured in arguments per day)
MP = Monthly mortgage or rent payments
C^3 = the speed of light cubed

While this formula may apply to some Amateur Radio endeavors, it is seriously flawed when it comes to satellites. In truth, over the past several years I have enjoyed many contacts with various spacecraft *without* owning the following items:

- A directional antenna array
- An RF power amplifier
- An RF preamplifier

How is this possible? By working the *EasySats*!

On the Wings of a DOVE

Do you own a 2-meter FM rig? How about an outdoor antenna of some kind? Excellent! You are now the proud owner

The author's 2-meter "EasySat" antenna is nothing more than a 5/8-wave groundplane attached to his chimney. The drooping cable above the roof connects to his HF dipole (not shown)—a perfectly adequate RS downlink antenna for 10 meters.

of a basic satellite receiving system—and there is a bird in orbit just waiting to talk to you. It's called AMSAT-OSCAR 17, otherwise known as *DOVE*.

DOVE is one of several *Microsats* presently in orbit. It transmits streams of packet telemetry and occasional bulletins on 145.825 MHz. By studying the telemetry, you can learn all sorts of fascinating things about conditions in space. Since DOVE is a *LEO* (*l*ow *e*arth *o*rbiting) satellite, its signal is very easy to hear.

If you only want to listen to DOVE's telemetry signal, you'll get an earful of raucous packet bursts as it streaks overhead. DOVE also has digital-voice capability and may be transmitting in that mode from time to time.

If you have packet equipment, you're in for an extra treat. Set up your terminal node controller (TNC) as you would for normal VHF-packet operation and switch your FM transceiver to 145.825 MHz. As DOVE rises above the horizon, you'll begin to see streams of data flowing across your monitor. You may also see brief text bulletins.

After you become tired of watching raw data, you'll want to find out what it means. There are several programs available to decode DOVE telemetry (see Fig 1).[1] I personally enjoy watching the decoded telemetry as the satellite passes the *terminator,* the dividing line between sunlight and darkness. By watching the satellite's solar array voltage, for example, you'll see an immediate effect as the satellite slips into earth's shadow.

DOVE has had a troubled history, with several failures during its career. Each time, however, AMSAT volunteers have managed to revive the satellite and get it back into working order. When DOVE is operating, it pumps out a strong signal. I've heard it clearly on a hand-held transceiver with just a "rubber duck" antenna.

The *Mir* Space Station

After you've discovered how easy it can be to eavesdrop on satellite signals, it's time to start thinking in terms of *transmitting* to a satellite. A perfect candidate for your first QSO is the Russian *Mir* space station.

Mir has been occupied by Russian cosmonauts for several years as a laboratory for testing human responses to long-duration space flights. These studies are extremely important for future manned missions to Mars and beyond. Cosmonauts who wish to operate the *Mir* Amateur Radio station are assigned special call signs (such as U9MIR). If they don't already hold Amateur Radio licenses, they are trained before lift-off.

Like the DOVE satellite, *Mir*'s signal is powerful. You'll usually find it on 145.55 MHz, and you won't need sophisticated equipment to hear it—or to be heard. Once again, an outside antenna—such as a groundplane—works fine. *Mir*'s orbit provides a couple of very good passes each day for most areas. (Just last month I

[1]AMSAT offers software to decode DOVE packet telemetry into meaningful data. They also offer satellite-tracking software for a variety of computers. Send a business-size SASE to AMSAT, PO Box 27, Washington, DC 20044 and ask for their software catalog.

DOVE DAYTIME TELEMETRY

RAW DATA

```
DOVE-1>TLM:00:5A 01:5A 02:88 03:32 04:59 05:58 06:6C 07:4A 08:6C 09:68 0A:A2
0B:EC 0C:E8 0D:DC 0E:3F 0F:24 10:D8 11:93 12:00 13:D1 14:9B 15:AE
16:83 17:7C 18:76 19:7E 1A:7C 1B:45 1C:84 1D:7B 1E:C4 1F:6C 20:CF
DOVE-1>TLM:21:BB 22:79 23:26 24:22 25:26 26:01 27:04 28:02 29:3A 2A:02 2B:73
2C:01 2D:7C 2E:58 2F:A2 30:D0 31:A2 32:17 33:6B 34:AC 35:A2 36:A6
37:A8 38:86 39:A2 3A:01
DOVE-1>STATUS: 80 00 00 85 B0 18 77 02 00 B0 00 00 B0 00 00 00 00 00 00
DOVE-1>BCRXMT:vary= 21.375 vmax= 21.774 temp=  7.871
DOVE-1>BCRXMT:vbat= 11.539 vlo1= 10.627 vlo2= 10.127 vmax= 11.627 temp=  3.030
DOVE-1>WASH:wash addr:26c0:0000, edac=0x61
DOVE-1>TIME-1:PHT: uptime is 086/01:14:32.  Time is Sat Mar 10 15:43:26 1990
```

DECODED TELEMETRY

DOVE uptime is 086/01:14:32. Time is Sat Mar 10 15:43:26 199

Rx E/F Audio(W)	2.21 V	Rx E/F Audio(N)	2.21 V	Mixer Bias V:	1.39 V
Osc. Bisd V:	0.51 V	Rx A Audio (W):	2.19 V	Rx A Audio (N):	2.16 V
Rx A DISC:	0.41 k	Rx A S meter:	74.00 C	Rx E/F DISC:	-1.08 k
Rx E/F S meter:	104.00 C	+5 Volt Bus:	4.94 V	+5V Rx Current:	0.02 A
+2.5V VREF:	2.51 V	8.5V BUS:	8.60 V	IR Detector:	63.00 C
LO Monitor I:	0.00 A	+10V Bus:	10.96 V	GASFET Bias I:	0.00 A
Ground REF:	0.00 V	+Z Array V:	21.38 V	Rx Temp:	7.26 D
+X (RX) temp:	-4.24 D	Bat 1 V:	1.35 V	Bat 2 V:	1.36 V
Bat 3 V:	1.38 V	Bat 4 V:	1.34 V	Bat 5 V:	1.37 V
Bat 6 V:	1.57 V	Bat 7 V:	1.36 V	Bat 8 V:	1.37 V
Array V:	21.32 V	+5V Bus:	5.30 V	+8.5V Bus:	8.85 V
+10V Bus:	11.54 V	BCR Set Point:	131.48 C	BCR Load Cur:	0.18 A
+8.5V Bus Cur:	0.06 A	+5V Bus Cur:	0.17 A	-X Array Cur:	-0.01 A
+X Array Cur:	-0.00 A	-Y Array Cur:	-0.01 A	+Y Array Cur:	0.12 A
-Z Array Cur:	-0.01 A	+Z Array Cur:	0.25 A	Ext Power Cur:	-0.02 A
BCR Input Cur:	0.45 A	BCR Output Cur:	0.29 A	Bat 1 Temp:	3.02 D
Bat 2 Temp:	-24.81 D	Baseplt Temp:	3.02 D	FM TX#1 RF OUT:	0.05 W
FM TX#2 RF OUT:	0.97 W	PSK TX HPA Temp	-3.03 D	+Y Array Temp:	3.02 D
RC PSK HPA Temp	0.60 D	RC PSK BP Temp:	-0.61 D	+Z Array Temp:	19.97 D
S band HPA Temp	3.02 D	S band TX Out:	-0.04 W		

Fig 1—Here's an example of packet telemetry you can expect to receive from the DOVE satellite. If you don't own a decoding program, you'll see only the raw data. However, with a decoding program the raw data can be converted into meaningful information.

listened to *Mir* in my car while driving home from work!)

Mir on Packet

The *Mir* Amateur Radio station uses AX.25 packet protocol at a data rate of 1200 bits per second—the same packet format most hams use here on earth. This means you *do not* need a special TNC to contact the station (see Fig 2). The *Mir* packet station includes a mailbox where you can leave messages for the cosmonauts (or anyone else), and pick up their replies.

The biggest problem with working *Mir* on packet is interference—lots of interference! With the signal coverage the space station enjoys, you can imagine how many hams might be trying to contact *Mir* at the same time. This creates pure chaos as far as its FM receiver is concerned.

If you're able to connect to the mailbox, the constant bombardment of signals may make it difficult for you to post your message before the space station disappears below your horizon. Here are a couple of tips to improve your chances:

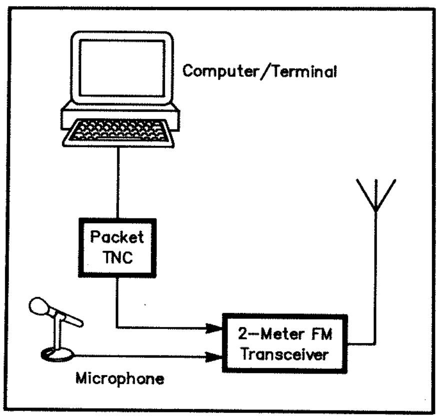


Fig 2—You don't need elaborate equipment to monitor DOVE telemetry, or to work *Mir* and SAREX. For packet operating, all that's required is a computer or data terminal, a packet TNC (terminal node controller) and a 2-meter FM transceiver. If you're interested only in voice contacts with *Mir* or SAREX, all you need is a 2-meter FM transceiver and a microphone!

- Listen before you start sending connect requests. Monitor a few transmissions and make sure you have the correct mailbox call sign. The call sign changes whenever a new crew occupies the station. (At the time of this writing, it was U8MIR-1.)
- Use as much power as you have available. If there were only a couple of stations competing for *Mir*'s receiver, you'd only need a couple of watts to have a decent chance of connecting. During a normal pass, however, there are usually *dozens* of stations blasting out connect requests. The stations that pack the bigger punches seem to win consistently.
- Try connecting during "unpopular" hours. If you have the stamina to sit up and wait for a late-night pass, you may have a better opportunity to make a connection.

When you finally connect to the mailbox, make your message entry *short*. The station will be out of range before you know it and other hams will be waiting to try their luck. Packet software that permits users to create message files in advance comes in handy for *Mir*.

Voice Contacts with Mir

The *Mir* cosmonauts obviously enjoy packet, but sometimes they crave the sounds of other human voices. You may be waiting for a chance to connect on packet, only to hear them calling CQ instead!

Talking to *Mir* is much easier than connecting to *Mir*—especially if you're using low power and omnidirectional antennas like I am. Working *Mir* is similar to working a DX pile-up. You sit with microphone in hand and wait until you hear the cosmonaut complete an exchange. At that moment you key the mike and say your call sign. Now listen. No response? Call again quickly! Keep trying until you hear him calling you or someone else. I've heard of mobile hams working *Mir* and some claim to have worked *Mir* with hand-helds. As you might imagine, *Mir* QSL cards are highly prized!

Mir cosmonauts tend to operate on an erratic schedule. They have many daily assignments and are not always able to find the time to operate their amateur station. In addition, they're sometimes forced to turn off their equipment altogether to avoid interference to other systems during critical tests.

The space station travels at a relatively low altitude, so it's always subject to a significant amount of atmospheric drag. If it didn't occasionally boost to a higher orbit, the station would reenter the atmosphere and be destroyed. Every time *Mir* fires its rocket engines to adjust its orbit, a revised set of *orbital elements* must be distributed. If you want to try your luck with *Mir*, plan to update your elements for the space station as often as possible (see the sidebar, "Finding the Satellites").

SAREX

SAREX, the *S*huttle *A*mateur *R*adio *E*xperiment, is a continuing series of Amateur Radio operations from US space shuttle missions. The first SAREX operations employed 2-meter FM voice, but more recent flights have also used packet, ATV and SSTV. The variety of modes in use depends on the available cargo space. In addition, not every shuttle astronaut is a licensed ham, so not every shuttle mission has an active SAREX operation. Check *QST* for the latest news on upcoming SAREX missions.

Unlike *Mir*, SAREX usually uses a 600-kHz split-frequency scheme to accommodate standard 2-meter FM transceivers. Earthbound DXpeditions use split-frequency operation to maximize the number of stations they can work. The same is true for SAREX. (If operating from outer space isn't a DXpedition, I don't know what is!) With this thought in mind, you can appreciate the importance of knowing which frequencies are being used for the uplinks and downlinks. (Monitor W1AW bulletins prior to liftoff for SAREX frequencies and other information.) Whatever you do, *never* transmit on the SAREX downlink frequency unless specifically instructed to. This mistake will make you very unpopular very quickly!

Finding the Satellites

All current Amateur Radio satellites are in nongeostationary orbits. This simply means that the satellites are not in fixed positions in the sky from our perspective here on earth. They are like tiny moons, rising and setting rapidly over your local horizon. While the satellites zip around the earth at tremendous speeds, the earth is turning beneath them. The result is that you can't rely on satellites to appear in the same places at the same times each day.

Orbital Elements

So how can you know when a satellite is about to make an appearance in your neighborhood? To answer that question you need to know the satellite's *orbital elements*.

As incomprehensible as it may seem, an orbital element set is merely a collection of numbers that describes the movement of an object in space. By feeding the numbers into a computer program, you can determine exactly where a satellite is (or will be) at any time. Don't worry about the definitions of *mean anomaly, argument of perigee* and so on. If you're curious, get a copy of the *Satellite Experimenter's Handbook** and you'll learn all about those definitions—and more. For the moment, consider the words as labels for the numbers that appear beside them.

Finding the Elements

There are several sources of orbital elements:

- Satellite newsletters†
- W1AW RTTY and AMTOR bulletins‡
- Packet bulletin boards
- Telephone bulletin boards**
- AMSAT nets‡‡

If you have an HF radio, RTTY/AMTOR capability, a packet TNC, a telephone modem or the necessary cash for a subscription, you'll always be able to get the latest orbital elements for the satellites you want to track. If all else fails, there is probably someone in your area who has access to the elements. Ask around at your next club meeting.

Using the Elements

Computers are common in most Amateur Radio stations today. If you have a computer in your shack, you're in luck! There are many programs on the market that will take your orbital elements and produce detailed satellite schedules.

Among other things, the programs tell you when satellites will appear above your local horizon and how high they will rise in the sky (their elevation). When working satellites, the higher the elevation the better. Higher elevation means less distance between you and the satellite with less signal loss from atmospheric absorption.

If you don't own a computer, you can calculate satellite positions using the ARRL *OSCARLOCATOR*.*** This manual method is a bit cumbersome compared to computers, but it beats relying on your best guess!—*WB8IMY*

**The Satellite Experimenter's Handbook* is available from your local dealer or direct from ARRL HQ. See the ARRL Publications Catalog elsewhere in this issue for ordering information.

†*The AMSAT Journal* is included with membership in AMSAT, PO Box 27, Washington, DC 20044. ($30 per year US, $36 Mexico and Canada)

OSCAR Satellite Report ($29 per year US, $32 Canada) and *Satellite Operator* ($33 per year US, $36 Canada) are available from R. Myers Communications, PO Box 17108, Fountain Hill, AZ 85269-7108.

‡W1AW transmits satellite orbital elements on Tuesdays and Saturdays at 2330 UTC using 45.45-baud Baudot RTTY, 110-baud ASCII and Mode B (FEC) AMTOR. Frequencies are 3.625, 7.095, 14.095, 18.1025, 21.095, 28.095 and 147.555 MHz.

**The Satellite orbital elements may be downloaded from the following telephone bulletin boards:
Dallas Remote Imaging Group (DRIG)—tel 214-394-7438;
Celestial RCP/M—tel 513-427-0674;
N8EMR—tel 614-895-2553;

‡‡AMSAT Information Nets:
Sunday at 1800 UTC on 21.280 and 14.282 MHz
Saturday at 2200 UTC on 21.280 MHz
Tuesday at 2100 Eastern Time on 3.840 MHz
Tuesday at 2100 Central Time on 3.840 MHz
Tuesday at 2100 Pacific Time on 3.840 MHz

***OSCARLOCATOR is available from your local dealer or direct from ARRL HQ. See the ARRL Publications Catalog elsewhere in this issue for ordering information.

You can use the same 2-meter equipment for SAREX as you do for *Mir*. During one of the packet robot operations on a previous flight, I managed to connect using my trusty groundplane. The shuttle was only 12° above my horizon at the time, but my signal still made it!

Most shuttle orbits favor hams who live close to the equator. American amateurs who live in the southern part of the country, for example, have always had a special advantage when it comes to contacting the space shuttle. However, the STS-45 mission earlier this year used a *high inclination* orbit. This provided several excellent opportunities for Yankees such as myself!

The RS (*Radio Sputnik*) Satellites

Have you ever heard of RS-10/11 or RS-12/13? They are unmanned Amateur Radio satellites placed in orbit by the former Soviet Union. Without a doubt they are among the easiest satellites to work.

The RS satellites are completely different from *DOVE*, *Mir* or the space shuttles. They are basically orbiting repeaters incorporated into larger satellite *platforms*. RS-10 and 11 are carried by *COSMOS* 1861; RS-12 and 13 are part of *COSMOS* 2123. There are two RS satellites per platform, but only one satellite is active at a time. (At the time of this writing, RS-10 and RS-12 were active.) All RS satellites are equipped with *linear transponders*.

Linear Transponders

Earthbound repeaters listen on one frequency and repeat what they hear on another. Imagine what would happen if your local repeater could retransmit everything it heard on an entire *group* of frequencies? This is exactly the function of a linear transponder.

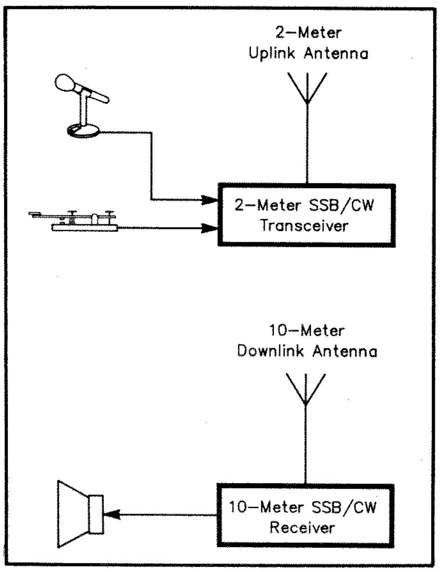
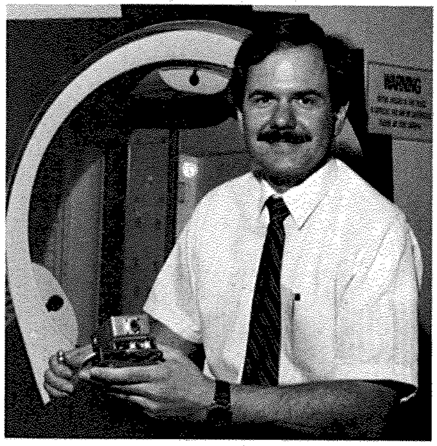


Fig 3—A diagram of a typical RS-10/11 or RS-12/13 mode A station. SSB or CW transmissions are sent to the satellites on 2 meters. The satellite downlink signal can be easily monitored on a 10-meter receiver connected to a wire dipole.



Payload Specialist Ron Parise, WA4SIR, operated from the space shuttle (STS-35) in 1990. His SAREX operation introduced Amateur Radio to schoolchildren around the country.

In *mode A*, the RS satellite transponder listens to a portion of the 2-meter band and retransmits everything it hears on the 10-meter band. When *mode K* is active, the transponder listens to a section of the 15-meter band and simultaneously retransmits on 10 meters. In *mode T*, the satellite listens on 15 meters and retransmits on 2 meters! The range between the highest and lowest uplink (or downlink) frequencies is known as the transponder *passband*. See the RS uplink and downlink frequencies listed in Table 1.

Not only do linear transponders repeat everything they hear on their uplink passbands, they do so very faithfully. CW is retransmitted as CW; SSB as SSB. *Do not* attempt FM voice transmissions on the RS satellites. FM is a 100% duty-cycle mode, meaning that your transmitter is generating full output *continuously* whenever you transmit. This places a severe drain on the transponder, causing it to reduce output.

Working the RS Satellites

As soon as you decide when you'll make your attempt, you have to determine which mode (and satellite) is active. Listening to the satellite itself will provide clues. You'll find that modes A and K are the most popular. On RS-10, mode A is usually available on a daily basis. RS-12, on the other hand, operates in mode K most of the time. Occasionally you'll find that two modes are active *simultaneously*—such as modes KA and KT.

For VHF enthusiasts, mode A is the most popular. If you have a 2-meter SSB/CW rig and a 10-meter receiver (see Fig 3), you're all set!

"I can receive on 10 meters, but I only have a 2-meter FM rig. I'll never be able to use mode A," the skeptic grumbles. On the contrary! Have you considered using your FM transceiver as a CW rig? All you have to do is wire a key to the push-to-talk (PTT) pins of your rig's microphone jack. Your signal may be a little raw and "chirpy," but you'll be transmitting usable CW! It's a great way to try the satellite before you invest in an all-mode radio.

Elaborate antennas are definitely *not* required to work the RS satellites. For RS-10, a wire dipole is fine for receiving the 10-meter downlink signal. By the same token, a basic groundplane is adequate for the 2-meter uplink. In terms of power, 10 to 20 watts seems to work well—although I've been able to work stations through RS-10 and RS-12 with only 2 watts output.

With the wide separation between uplink and downlink frequencies, you can work the RS satellites in *full duplex*. In other words, you'll be able to hear your own signal on the satellite downlink *while you're transmitting*! When you communicate through the RS satellites for the first time, make sure to keep one hand on your uplink VFO. That's to offset a pesky little problem known as *Doppler shift*.

The Mystery of the Shifting Signal

Doppler shift is caused by the difference in relative motion between you and the spacecraft. As it moves toward you, the signal frequencies in the downlink passband gradually *increase*. As it starts to move away, the frequencies *decrease*. It's the same effect you hear when a speeding railroad locomotive blares its horn. The frequency of the sound rises as the train moves toward you. As it passes your position and moves away, the frequency decreases. (Keep this in mind the next time you're stopped at a crossing. Listen to how the locomotive horn sounds *before* and *after* it reaches the crossing.)

When I made my first RS contact on CW, I noticed that I had to adjust my

Finding Your RS Downlink Signal

If you know your RS uplink frequency, how can you predict where your signal will appear in the downlink passband? Here's a calculation you can use that will get you in the ballpark:

$F_{Down} = F_T + F_{Up}$

F_T is the *translation constant* in megahertz and F_{Up} is your chosen uplink frequency. For RS-10/11 and RS-12/13, the F_T value depends on the mode:

Mode A: −116.5 MHz
Mode K: 8.2 MHz
Mode T: 124.7 MHz

Let's use mode A on RS-10 as an example and assume that you've chosen 145.870 MHz as your uplink frequency.

$-116.5 + 145.87 = 29.37$ MHz

See how easy it is? If you're transmitting on 145.87 MHz, you can expect to find your downlink signal near 29.37 MHz.—*WB8IMY*

Table 1
EasySat Frequencies
RS Satellites

	RS-10	*RS-11*	*RS-12*	*RS-13*
Mode A				
Uplink	145.860-145.900	145.910-145.950	145.910-145.950	145.960-146.00
Downlink	29.360- 29.400	29,410- 29.450	29.410- 29.450	29.460- 29.500
Beacons	29.357/29.403	29.407/29.453	29.408/29.454	29.458/29.504
Mode A ROBOT				
Uplink	145.820	145.830	145.830	145.840
Downlink	29.357/29.403	29.407/29.453	29.454	29.504
Mode K				
Uplink	21.260- 21.200	21.210- 21.250	21.210- 21.250	21.260- 21.300
Downlink	29.360- 29.400	29.410- 29.450	29.410- 29.450	29.460- 29.500
Beacons	29.357/29.403	29.407/29.453	29.408/29.454	29.458/29.504
Mode K ROBOT				
Uplink	21.120	21.130	21.129	21.138
Downlink	29.357/29.403	29.403/29.453	29.454	29.504
Mode T				
Uplink	21.160- 21.200	21.210- 21.250	21.210- 21.250	21.260- 21.300
Downlink	145.860-145.900	145.910-145.950	145.910-145.950	145.960-146.00
Beacons	145.857/145.903	145.907/145.953	145.912/145.958	145.862/145.908
Mode T ROBOT				
Uplink	21.120	21.130	21.129	21.138
Downlink	145.857/145.903	145.907/145.953	145.958	145.908

DOVE: 145.825 MHz FM simplex.
Mir: 145.55 MHz FM simplex.
SAREX: See *QST* or monitor W1AW bulletins for uplink/downlink frequencies prior to launch.

2-meter transmitter as my downlink frequency began to shift. If the satellite is particularly busy, it's possible for one QSO in progress to collide with another! As you gain experience with the satellite, you'll discover how to select uplink and downlink frequencies that minimize the chances of a collision. (Because of the wide bandwidth characteristics of 2-meter FM transmissions, Doppler shift is not a serious problem when working *Mir* or the space shuttle.)

RS Operating Techniques

Since the satellites are available for only about 10 or 15 minutes during each pass, contacts tend to be brief. CW operators generally congregate in the lower half of the transponder passband while SSB operators occupy the upper half.

If you hear someone calling CQ on SSB, note the downlink frequency and *quickly* tune your uplink transmitter accordingly. As you answer the call, adjust your transmitter until your voice is clear and audible on the downlink. You can even do this *while the other station is still calling CQ*. I've heard some SSB operators adjusting their uplink frequency and saying, "Test, test, test..." By using this method they're assured of being on-frequency and ready to respond when the other station stops calling.

Answering a CW call is just as easy. As soon as you copy the call sign, tune your uplink transmitter to the proper frequency and start sending a series of *dots*. Listen on the downlink and adjust your transmitter until you hear the tone of your CW signal roughly matching the tone of the station sending CQ.

If you're using a 2-meter FM rig as your CW uplink transmitter, you're probably limited to tuning in 5 kHz steps. This makes it difficult for you to tune onto other stations when they're calling CQ. In this situation it's often best to simply stay in one place and call CQ yourself. The hams who own the more agile radios will come to you!

The RS satellites also carry unique devices known as *ROBOTs*. When they're active, they call CQ about once per minute using CW. (ROBOT frequencies are shown in Table 1.) To answer a ROBOT, your signal must be within its 2-kHz-wide *receive window*. Don't forget to take Doppler shift into account when you select your uplink frequency! To contact the RS-10 ROBOT, I'd send:

RS10 DE WB8IMY AR

With any luck I'll hear this response:

WB8IMY DE RS10 QSO NR 589 OP ROBOT TU FR QSO 73 SK

The three-digit QSO number (589 in our example) is incremented after each contact. If the ROBOT only gets part of your call, you may hear it send QRZ, QRM or RPT. If you're sending too fast or too slowly, it may respond with a QRQ (send faster) or QRS (send slower).

Now That You're Hooked...

After you've been working the EasySats for a while, you'll begin to wonder how difficult it is to work the other Amateur Radio satellites. The answer is: much easier than you think!

Take the PACSATs, for example. They're packet satellites with tremendous capabilities. Some function like orbiting packet bulletin boards. Others carry video cameras and transmit images of the earth and other objects in space. To communicate with the PACSATs you'll need to add 435-MHz SSB receive capability along with a specialized TNC and software.

If you prefer CW or SSB contacts, don't forget AMSAT-OSCAR 13—the DX satellite! You'll need directional antennas and SSB/CW capability on 2 meters and 70 cm, but it's relatively inexpensive to assemble an OSCAR 13 ground station. Believe me, the reward is well worth the effort! We'll discuss the PACSATs and OSCAR 13 in more detail in future articles.

For now, enjoy yourself on the EasySats. If you hear me on the RS birds, give me a call. I'm working toward getting my VHF/UHF Century Club—Satellite award and I need all the contacts I can get! QST

An FM Repeater in Orbit: OSCAR-21

In May of this year, AMSAT-DL announced it had temporarily activated an experimental FM voice repeater aboard AMSAT-OSCAR 21 (also known as RS-14). The uplink frequency is 435.016 MHz and the downlink is 145.987 MHz. The repeater is active only for the first four minutes of each 10-minute period (for example, from 1420 to 1424 and again from 1430 to 1434).

OSCAR-21 is a joint project of AMSAT-DL and a Russian group. It was launched into a 600-mile-high orbit in 1991 aboard a Russian GEOS satellite. OSCAR-21 also carries two linear transponders for SSB/CW and a RUDAK packet data transponder. (See the *ARRL Operating Manual* and *Your Gateway to Packet Radio* for more information.) OSCAR-21 is a developmental satellite, so the transponders in use change frequently. Check your satellite news sources for the latest updates on the status of the OSCAR-21 FM repeater.—*WB8IMY*