ARRL Handbook CD

Template File

Title:	Repeaters
Chapter:	15 (1995 ARRL Handbook Reference Material)
Topic:	Planning, Siting and Operating a Repeater

AT THE REPEATER SITE

Transmitters, Receivers, Duplexers, Antennas—Looking at the Pieces

When a piece of equipment breaks down in an individual's ham station, it is usually a quiet occurrence. Only the ham and those with whom he has a scheduled contact know there is a problem. When a repeater fails, it is a community-wide occurrence; the breakdown may affect hundreds of people.

Therefore the primary factors in selecting a piece of repeater equipment to build or buy are general reliability and matching the equipment to the expected use. If the repeater is going to be in an unheated room on a mountaintop it has to stand up to the temperatures found in that location — perhaps −40°F in the winter and +120°F in the summer.

On the other hand, if the repeater shares a closet with other commercial communications gear on the top floor of a large building, a temperature in excess of 140°F may not be uncommon — all this with the need for almost 100% duty cycle at times.

Repeater hardware most commonly comes from one of three sources — commercial repeaters purchased as a complete package, transmitters and receivers taken out of commercial service and modified for Amateur Radio, and home-built equipment.

In order to examine each of the pieces of a repeater, the total system design has to be well thought out. The objective of the system design is for a station, say John Q. Mobile, to hear the repeater "full quieting," and the repeater to hear the mobile "full quieting."

Full quieting is the condition that occurs when a signal into a repeater is sufficiently strong that only audio and no noise is heard.

The general equation from the repeater to the mobile can be expressed as:

At the Repeater
[Transmitter Power Output − Feed-Line Losses − Duplexer Losses + Antenna Gain] − Path Loss
+
At the Mobile Station
[Antenna Gain − Feed-Line Losses]
=
Minimum Signal Needed at a Low to Moderate Quality Mobile Receiver.

The equation the other way, from the mobile to the repeater, can be expressed as

At the Mobile Station
[Transmitter Power Output − Feed-Line Losses + Antenna Gain] − Path Loss
+
At the Repeater
[Antenna Gain − Feed-Line Losses − Duplexer Losses]
=
Minimum Signal Needed at the High Quality Repeater Receiver

From these relationships it is clear that repeaters can be configured to resemble simple mobile stations if losses are kept low at the repeater site, and the mobile station equipment and that of all other users conform to a certain power level and sensitivity. However, since some transceivers put out less than 1 W of power, and antenna gain can be minimal, the repeater is configured to compensate for deficiencies in the stations using it.

Thus, most repeaters with reasonable antennas and losses tend to run 10 to 25 W for small areas and 50 to 100 W for wider coverage. It also means that most repeaters use antennas with gains of 6 or more dBd.

Transmitters

As we have seen, the power level of the transmitter is a primary factor in repeater coverage performance, and can be traded off against lower-loss feed lines and high-gain repeater antennas. The second factor in transmitter selection is spurious emissions and noise. *The ARRL Antenna Book* has a set of design examples and graphs that can be used to determine specific requirements for the antenna and other system elements vs transmitter power.

Noise and other spurious signals emitted from the transmitter have three major effects. First, they may affect other receivers in the area. Most good repeater sites are shared with commercial and state and local government communications equipment whose owners and users would take a very dim view of one of the Amateur Radio repeater's spurs entering their equipment. Second, these spurs have the potential of combining with other signals to feed back into the repeater's receiver, as will be discussed later in this chapter in the section on interference problems. Finally, the level of the transmitted noise is a direct factor in determining the level of isolation needed from the duplexer. Given the repeater offset (600 kHz, 1, 1.6, 5 or 12 MHz), the transmitter noise at this offset frequency appears as an input signal. Raise the noise by 10 dB and the duplexer isolation must be raised by 10 dB. This is very important when you wish to use either a converted commercial transmitter (taken from mobile service) or an inexpensive "brick" amplifier. While they may be suitable for use at home or in a vehicle, they may not have sufficient noise or spurious suppression to make them suitable for the repeater.

An additional factor is environmental considerations. In addition to having to withstand local ambient conditions (building air conditioning has been known to fail, especially during local emergencies), the need to withstand 100% duty cycle for long periods of time usually requires the addition of heat sinks and active cooling such as fans.

Further discussion of transmitter specifications, problems and cures can be found in the ARRL book *Radio Frequency Interference: How to Find it and Fix It.*

Receivers

Nominal receiver sensitivities of 0.2 to 0.3 µV are usually suitable for repeater use. The more critical factor is the receiver performance in the presence of strong signals. As will be discussed in the section on repeater interference problems, the front end of a receiver must have sufficient dynamic range to withstand the total power it receives at any one time — be that power due to a desired signal, leakage from the repeater transmitter, or any other signals that come down the feed line and are not rejected by the duplexer.

A full discussion of dynamic range and the effects of front-end problems appears in the **Transceivers** chapter. Additional background information on the mixing process is in the chapter on **Mixers, Modulation and Demodulation**. In summary, the receiver front end must remain linear so that no mixing with undesired signals takes place. This helps reduce "intermod" and other common repeater problems to be discussed later in this section.

For this reason, adding a preamplifier is rarely effective in extending repeater range. The need for more signal amplitude is better fulfilled by antenna improvements and reduction of system losses, especially in the feed line. In many repeater environments, composite signal voltages from all of the nearby VHF and UHF sources can be on the order of volts.

Antennas

A full description of antennas, gains and patterns can be found in *The ARRL Antenna Book*. While there is no question that a simple ¼-λ antenna may suffice for a repeater, a higher gain antenna is often desirable. Similarly, while an omnidirectional donut or torus pattern such as that provided by such a simple antenna will also suffice, siting of the repeater will often suggest that a modified pattern is in order. See **Fig 23.15**.

While most attention is usually focused on the electronic properties of the antenna, the mechanical properties eventually provide the most challenges and problems. The antenna is exposed to the elements — 24 hours a day, 7 days a week, 365 days a year. Heat, cold, humidity, salt spray, acid rain, condensate from cooling towers — these are the normal elements in the antenna's life.

In addition cuts, scrapes and nicks caused by handling during installation or by contact by other antennas or other equipment as it is erected on the site tend to reduce the environmental protection at the antenna. While certain precautions are familiar — the use of stainless-steel hardware, correct torque on fasteners and sealing transmission-line connectors properly — others, such as locating the clamps and fasteners where they can be periodically maintained, are not obvious.

Repeater Sites

There is no single primary factor in selecting a repeater site. In well-populated areas, any suitable site is probably already occupied by other communication antennas, and the real questions are which site do you want, and can you get permission to place a repeater there?

In answering the question as to which site you want, it is best to start with US Geological Survey (USGS) maps. The maps provide altitude contours at intervals that can be used to determine coverage and shadow areas.

An approximate formula for repeater coverage over real Earth (not flat Earth) is

$$\text{Range in miles} = 1.41\left(\sqrt{\text{repeater ant height}} + \sqrt{\text{mobile ant height}}\right)$$

where the location of the antenna center of radiation is the antenna height in feet.

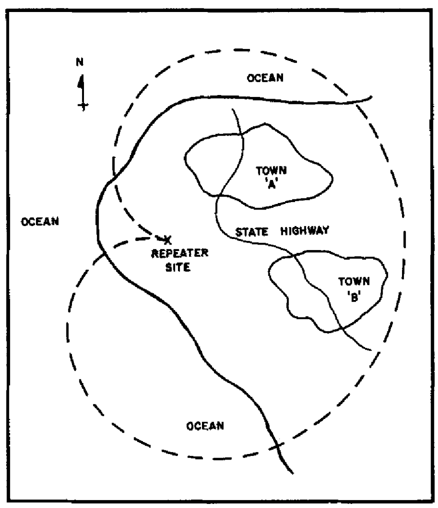

Fig 23.15 — In some cases, depending on terrain, it may not be advantageous to have equal coverage in all directions from the repeater. To cover towns A and B, and the highway between them, an antenna with a radiation pattern shown with the dashed line is preferable to one with an omnidirectional pattern.

This equation is good to two significant figures and varies slightly with frequency, terrain fringing effects and soil/water conditions.

Fig 23.16 demonstrates how to use a USGS map to determine shadow areas. At the left side the plus sign is the proposed location of a repeater on a 400-ft hill. This could just as easily be a 400-ft building. The contours are a simplification of what would be seen on a USGS map — here the contours are every 25 ft. The X at the right side is the location of a mobile station, and it is located somewhere between 350 and 325 ft elevation, which are the two closest contours.

First, draw a line (shown here as the dotted line) connecting the mobile and repeater stations.

Next, place a piece of graph paper over the map with one axis parallel to the line just drawn. In the figure, this graph paper axis is line AB. Perpendicular to this axis, label the other axis with the range of altitude contours that are in the line from the repeater to the mobile. In this case they range from 300 to 400 ft.

Drop a line from the repeater site toward the AB line, stopping it at the altitude of the repeater — here 400 ft. Make a mark.

At each intersection of a contour with the dotted line drop another vertical toward A B, making a mark at the corresponding altitude. Continue to do this at all crossings including the mobile station plus one more contour past the mobile (points D and E).

Connect the points (dashed line) and you now have a cross section of the terrain between the mobile and the repeater. The second dotted line (CD) is the line of sight from the repeater to the mobile. If it easily clears the intervening hills you have full coverage. In this case it appears somewhat marginal (about 12.5 ft of shadow) and therefore you will get less than optimal coverage.

Once you have decided on the desired site it is a matter of getting permission to use it. The fact that other commercial users are already there can work to your advantage since the owner of the site will have had previous experience with the concept and you will not have to provide an instant technical education. Stress the public service aspect. If possible tie in with the local Civil Defense/Civil Preparedness/Emergency Support group and encourage the town, police or other service that supports the emergency group to support you in the negotiations.

Many federal government areas have specific policies concerning siting and fees, although local federal officials may not be aware of them and you may have to contact Washington directly to obtain the policy.

In selecting a physical location remember that you will not only be at the site when you install the repeater but also for maintenance. Plan ahead.

In effect, imagine a worst case scenario. In the US southwest the temperature is 110°F, it is the 4th of July, everyone is on vacation, and the repeater transmitter is hung on and rebroadcasting the local rock station on 146.76. In the north the corresponding scenario is New Year's Day with new fallen snow adding up to 27 inches. In the southeast a hurricane is expected tonight with a rainfall potential of 12 inches in 4 hours. These are times the repeater will need maintenance, and recognizing this, certain sites are probably not a good choice.

Site Questions

- Can I reach the site in all weather at all times of the year?
- Who has the key?
- Is the equipment secure?
- Is there power for test equipment? Lights for working? Heat/air-conditioning?
- How reliable is the power source?
- Is emergency power available?

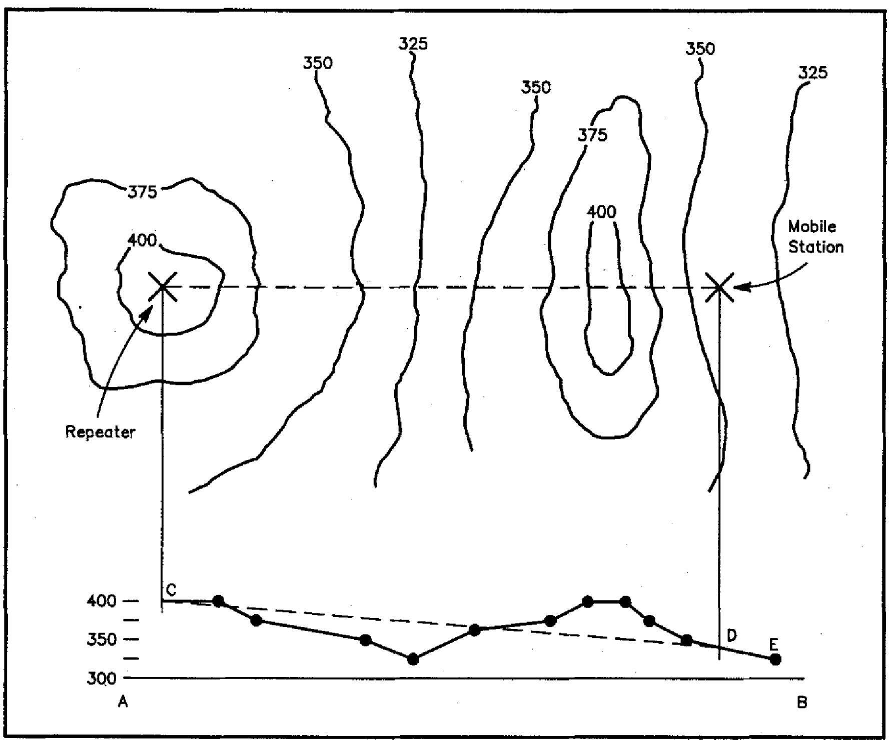

Fig 23.16 — A US Geological Survey map can be used to determine repeater shadow areas. See text.

Planning a Repeater

Resources

A successful repeater requires a lot of planning and more information sources than this book. If you are considering installation of a repeater, you should acquire:

The ARRL Repeater Directory — The latest edition contains an up-to-date catalog of registered repeaters in your area, repeater registration cards and a list of local frequency coordinators.

US Geological Survey (USGS) map (scale 1:250,000) — The map shows information about roads and elevations that you need to determine a suitable repeater location, its height above mean sea level (AMSL) and the repeater height above average terrain (HAAT).

The FCC Rule Book (published by the ARRL) — This book contains FCC Part 97 Rules and Regulations, along with a detailed discussion about the meaning and application of those rules. An entire chapter is devoted to "Repeaters and Control."

The ARRL Antenna Book — Chapters about "Repeater Antenna Systems" and "Radio Wave Propagation" tell how to tailor the antenna system to your service area and how to determine the service area that your repeater will reliably cover (for normal terrain).

Manufacturers' Catalogs — Some makers of repeater equipment have design aids to help communication-system designers.

Height Above Average Terrain

HAAT is a reasonable measure of the efficiency of your proposed repeater site across the coverage area. Some repeater coordinating councils require this figure for repeater registration.

To determine the HAAT of a repeater site, use the USGS map discussed previously with a scale of 1:250,000. Lay out eight even-spaced radials (0, 45, 90, 135, 180, 225, 270 and 315°) that extend 10 miles from the antenna location. Read and record the terrain elevation at the map contour line closest to each radial at distances of 2, 4, 6, 8 and 10 miles from the antenna location. Total the elevations and divide by 40 (the number of measurements you've made) to compute the average height of the terrain surrounding the antenna, AT. HAAT is then the height (AMSL) of the antenna center of radiation less the computed average height of terrain (see **Table 23.6** for an example).

Common Problems

There is a rule in many laboratories and electronic test facilities: When you are trying to fix a problem, change only one thing at a time. For that reason the best approach to most repeater problems is to change only one thing at a time — but this supposes that you know where you have started from. For this reason, it is advisable to run a set of tests on any working repeater to establish a baseline. Then when a problem arises you will know where you were, and any changes will lead you toward the solution.

Some of the tests (with results recorded in a logbook) should be performed at the repeater site. These include SWR, power output and transmitter spectrum (if a spectrum analyzer is available). The receiver should also be measured — noise figure, minimum signal to enable limiting and, optionally, bandwidth.

It is also a good idea to measure the power needed (with a fixed antenna from another location) to put the receiver into limiting, as well as a measure of the received signal strength at this other location. Doing this periodically at two or three points around town allows you to monitor the repeater's health.

Finally, log the antennas and other communication-related units in proximity to your repeater. Should a problem suddenly arise it is helpful to know that before that

Table 23.6
Computing Height Above Average Terrain (HAAT)

	Height Data							
Distance (Miles)	*0°*	*45°*	*90°*	*135°*	*180°*	*225°*	*270°*	*315°*
2	1500	1400	1400	1500	1500	1400	1450	1500
4	1450	1250	1300	1400	1350	1400	1350	1350
6	1300	1150	1200	1250	1250	1200	1200	1250
8	1100	1000	1000	1000	1050	1000	900	1000
10	1000	900	800	750	750	850	850	925
	6350 +	5700 +	5700 +	5900 +	5900 +	5850 +	5750 +	6025 = 47175

Tower base is 1450 ft AMSL.
Antenna center of radiation is 63 ft above tower base.

Computation
AT = 47175 ÷ 40 = 1179.375 ft AMSL
HAAT = 1450 + 63 − 1179 = 334 ft

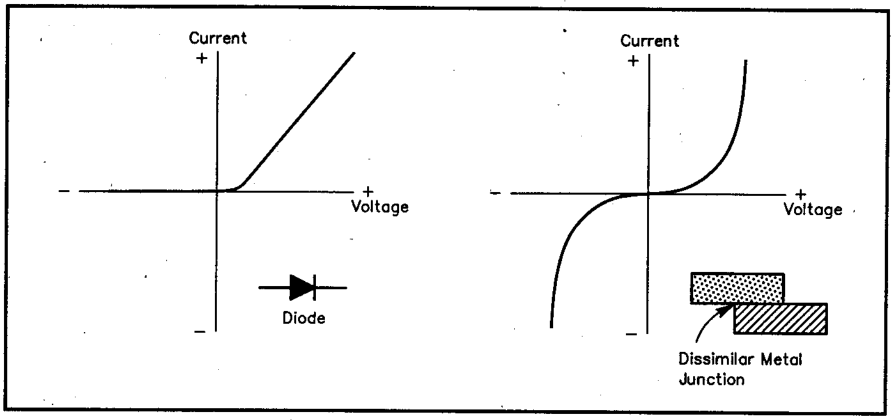

Fig 23.17 — Two types of nonlinear devices that can cause intermodulation interference problems, the diode and the dissimilar-metal junction.

new commercial repeater was installed 10 ft away from your machine you had no problem and now you do. The commercial repeater alone may not be the problem but it may be contributing. By periodically noting the changes near the repeater site you can save considerable time and effort.

Intermodulation distortion, or intermod, is a common problem that has the general characteristic of occurring and disappearing intermittently. It is generally due to the presence of other transmitters in the area as well as nonlinear devices.

The two major classes of nonlinear devices are shown in **Fig 23.17**. The first, a diode, produces current flow in only one direction and after an initial junction bias is overcome (0.1 to 0.5 V), the current is almost proportional to the applied voltage but only in one direction. The other device is a junction made of two dissimilar metals. Here too, there may be a small junction bias but the device often does not rectify. It simply produces a current flow that is not proportional to voltage. Both the diode and the dissimilar-metal junction can be the culprits in an intermod problem.

Tower construction bolts, cable clamps, sheet metal, guy wires — all of the items that surround your repeater antenna are capable of taking one or more signals, perhaps combining them alone or with your transmitted signal, and providing a resultant signal in your repeater receiver passband.

As you might imagine, you will usually see the diode case only when there is electronic equipment around. Your own repeater receiver when fed enough voltage (a composite of all signals reaching it) will act as a mixer to produce intermod, as will other receivers in the area. Since most repeater sites are populated with a number of other communications units it is not surprising that intermod is common.

Paging transmitters are a well-known source of intermod. When the transmitter is on they can produce one of the signals that are mixed to provide the interfering signals. However, they usually consist of a solid-state transmitter followed by some minimal filtering between the transmitter and the antenna. When the transmitter is off, the transistors in the final amplifier can act as a mixer — they are the diodes needed to provide the nonlinear action and therefore provide intermod signals. A good source of information on this topic is the ARRL publication, *Radio Frequency Interference: How to Find It and Fix It.*

A second effect, called *desensing*, also causes poor repeater performance. Desensing occurs when a large signal reaches the receiver and changes the receiver input operating conditions to a point where the desired signals are no longer amplified. It most commonly occurs when a repeater is poorly designed or built, and the repeater transmitter provides this large signal into the receiver. It can also be caused by one or more other transmitters in the vicinity of the repeater. The receiver basically blocks — does not amplify — and the result is partial or complete loss of sensitivity.

In addition to relocating of the antenna, the only other primary solution to this problem is filtering of unwanted signals.

Weather and environmental conditions can also cause problems. Occasionally it is almost impossible to sort out the cause of a problem and only by keeping a log of the operation can one obtain a clue. Outside temperature, wind speed, wind direction (salt fog coming off the ocean, for example) all can provide intermittent problems.

Rogue Transmitters — Small transmitters used for remote control often also provide an intermittent source of interference. Although regulated by the FCC with limits on duty cycle and power, they unfortunately are not well controlled and certainly never serviced after initial manufacture. Garage door openers, remote light and alarm controllers, and capacitive touch plates for home lights all can provide interference.

One particular nationally distributed model of a television preamp is well known for its effect. Well behaved when installed, it seems to go unstable whenever the television set has been disconnected. The usual scenario begins with a family moving. The booster amplifier is on the outdoor TV antenna and the power supply left plugged in. With no TV set as a load the amplifier takes off, oscillating and sweeping in frequency across the entire VHF and UHF spectrum. The "swish/gurgle" noise you hear on the repeater from time to time is this little unit. Of course, no one is home so you cannot get into the house or apartment to track the culprit down!

Controllers and Control Functions

The first few generations of ham repeaters used hand-wired controllers — when a new function was to be added, a piece of add-on hardware was built and the function implemented. Diode programmed Morse code identification generators, 555-based timers, DTMF generators and encoders based on PLL loops, and other discrete circuits were widely used. As digital technology became more affordable this approach evolved to software-based controllers, where after implementing a baseline set of functions it is only necessary to add software modules and perhaps I/O (input/output) cards.

Purchased repeaters include controllers that have a preset library of functions. One such set of functions is shown in **Table 23.7**. This represents a moderately complex repeater; there are repeaters with far more functions and far fewer functions. The designation XXXXX represents a set of digits, including * and #, which are themselves programmable.

Almost all of the functions shown can be set to come on line automatically. As an example, when the repeater is brought up by a user after some period of silence the outside temperature and local time can be programmed to be announced by a voice synthesizer. Likewise, turning on any of the functions shown — or turning them off — can be confirmed either by a Morse code letter or by the synthesized voice. Call letter identification (ID) is an exception to this programmability. It is preset to conform with the latest FCC requirements. You can get up-to-date information in this area by looking in the ARRL publication *The FCC Rule Book.*

Voice identification is appropriate at all times. However, it is distracting when the repeater is in actual use. Therefore, voice ID is used only at the beginning of a period of use and for one ID after use. During actual repeater use, Morse code ID can be accomplished in the background without covering the repeater audio of the users.

Home-built controllers are generally implemented in one of two ways — either by using a desktop computer (PC compatible, Mac or Apple) or by using a program-

Table 23.7
Typical Controller Functions

DTMF Command	*Function*
(X signifies a digit 0 to 9 as received over the repeater receiver)	
*XXXX	repeater off — night mode (automatically in night mode 11 PM to 6 AM)
XXXX	repeater up — night mode (will remain on as long as inputs are not absent for more than 15 seconds)
#X	check mailbox for messages (reverse autopatch and messaging available but not enabled)
#X YY	retrieve messages for user YY
#X YY	leave message for user YY (follow voice prompts)
#XX YY	cancel messages for user YY
#XXX	canned messages
*XXX	turn on wx radio 162.55
*XXX	turn on wx radio 162.475
*XXX	turn on wx radio 162.4
*XXX	turn on aux radio receiver #1 (provision for ELT)
*XXX	turn on aux radio receiver # 2 (provision for WWV)
*XXX	turn off all aux radio receivers
*XXXX	turn off remote repeater receiver (default is on)
*XXXX	turn on remote repeater receiver
#XXX through #XXX	for remote base and linking commands
*X	autopatch on
#X	autopatch off
**X	on autopatch mobile will not be heard over the air
**X	last number redial
0 through 9	emergency autopatch speedial (local town police, state police, fire, ...)
selected numbers 11 through 99	user speedial
#X	repeater S-meter reading (mobile signal strength)
#XX	frequency error of input signal
#XX	deviation of input signal
#XX	outside temperature
#XX	inside cabinet temperature
**ZZ	page user ZZ (with CTCSS tone)
*#ZZ	page user ZZ (with DTMF tone sequence)
Reverse paging from telephone available but not implemented	

mable microprocessor — commercially available "computers on a board." The latter are available from a number of sources with memory, I/O and software development packages, including RTOS (real-time operating system). They do require a fairly high level of skill to configure and program. Both disk-based and ROM-based storage are available for the software used with these units.

Controllers based on desktop computers have the advantage of being able to call upon a large number of software language packages, development tools and I/O cards for use as a standalone controller. Several problems have to be recognized:

1) Technique for reset when power is lost or intermittent.

2) RFI — both computer generated into the repeater receiver and computer susceptibility to the repeater transmitter.

3) External control on reset (generally from a remote location) if the repeater malfunctions.

While these are not difficult issues to deal with, they must be recognized in advance.

Flow charts for a software-based repeater controller design are available upon request from the ARRL Technical Secretary with an information package. Request the '95 *Handbook* Repeater Controller template package.

Power Sources

An ideal repeater site would provide emergency power. If a repeater is located in a hospital or office tower such sources of power are often available. Lacking this fortuitous arrangement, most repeaters are configured with backup power from either generators or charged batteries. It is common to take the final repeater amplifier off line when backup power is used, allowing longer battery life in this emergency mode.

The **Power Supplies** chapter contains recommendations applicable to repeaters as well as several suggested backup power source chargers, solar units and regulators.

OTHER REPEATER CHOICES

Networked Repeaters

Linked repeaters were mentioned earlier in this chapter. Almost any number of such repeaters can be linked, and by using auxiliary stations or wide-area repeaters, this linking can and does take place over both large geographic areas (in square miles) and large linear distances (town to town and through a number of different states). Except for possible traffic loads (and the availability of repeater frequency assignments), there is no reason that several intercontinental links cannot exist.

The control functions, usually using dial up (DTMF) tones and subaudible (CTCSS) tones, should be planned in advance with a modular concept in mind. In addition, auxiliary functions such as remote base stations and special service receivers can and often are incorporated in these linked systems. Generally, each transmitter must be capable of having its own identifier and suppressing the identifier of units up and down the link so the transmitter, when transmitting an ID, cannot be mistaken for another unit on the link. Familiarity with the FCC rules on auxiliary stations, control and identification is essential.

Amateur Television (ATV)

Some areas have wideband repeaters, designed for use with amateur television (fast-scan TV). These machines can be put on any band where ATV is legal. The band plans for 420 MHz and up (as detailed in the *ARRL Repeater Directory*) include ATV repeater assignments 6 MHz wide for those bands that have a detailed band plan. Contact your local frequency coordinator for the latest information on those bands that do not have a band plan in the current *ARRL Repeater Directory.* **Fig 23.18** shows a solar-powered ATV repeater.

Digipeaters

Digipeaters, or digital repeaters, are an integral part of most packet stations. The concept is to allow any station to be repeated through another station on its way to a destination. Packet radio is a digital communication technique using time division multiplex — that is, all stations wishing to communicate through a point use the same RF frequency (single-port operation) and take turns. Therefore, the multiplexing of several stations takes place over time. A digipeater may also be set up to have two ports with one on a 2-m frequency and the other on a second band such as 440 MHz.

In contrast to an ordinary voice repeater, a digipeater is not "real time." While a voice (or ATV) repeater has a receiver accepting an input signal and a transmitter simultaneously retransmitting the signal, a digipeater accomplishes only one function at a time. A number of packets are received, stored and then retransmitted.

Most areas have a large number of nodes that are accessible directly so most hams do not have to use a neighboring ham's packet station to be repeated. More-detailed information on digipeaters and packet radio can be found in the ARRL publications *Your Packet Companion* and *Your Gateway to Packet Radio*.

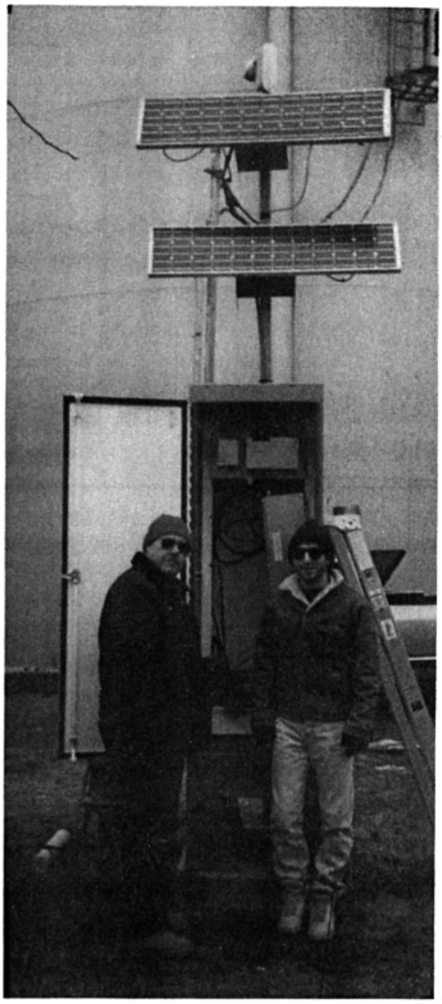

Fig 23.18 — This solar-powered ATV repeater is located in central New Jersey. The system features a remote-controlled beacon and an omni-directional antenna atop the water tower in the background. *(photo courtesy N2RPK)*

Multichannel Repeaters

Later in this chapter there is a discussion of transponders, which are found on the various amateur satellites. Many of these transponders, as contrasted to a typical FM voice repeater, can carry or repeat many QSOs at once. The preceding paragraphs called a digipeater a "time division multiplex system," since all QSOs were carried on the same frequency but time was shared. The satellite systems are generally "frequency division multiplex," since all conversations are carried on at the same time but on different frequencies. This is possible since the satellite transponder consists of a wideband receiver and a wideband transmitter. Any signal going to the transponder that is within the receiver bandwidth is translated in frequency and retransmitted.

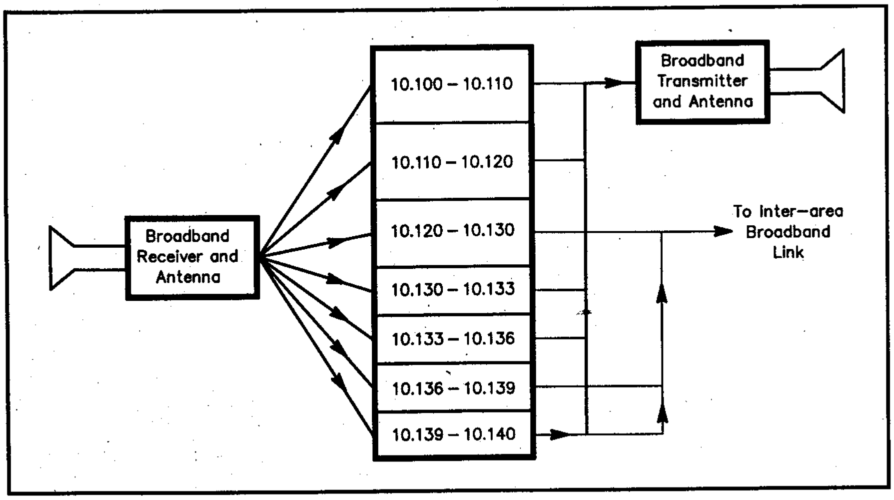

Fig 23.19 — An example of a wideband, 10-GHz repeater, with frequencies allocated in accordance with the suggested band plan.

Therefore, if we assume we can have a QSO each 5 kHz and the transponder bandwidth is 100 kHz, from a frequency point of view 100/5 = 20 QSOs can be repeated at once. The practical situation is, of course, not quite as simple. One drawback is that the total transmitter power is divided among all of the signals in the passband. Thus, coverage may change when there are more users. Also, a single, very strong signal can decrease the strength of other signals in the passband.

There is no reason wideband repeaters cannot be put into service in ground-based applications as long as the bandwidths occupied are within the FCC rules for the band, and they conform to the band plan.

Fig 23.19 illustrates the concept of a wideband repeater. It is shown on the 10-GHz band. In accordance with the band plan published in the *ARRL Repeater Directory*, the frequencies 10.364 to 10.368.4 GHz have been partially allocated and are not used for this repeater.

A second limitation in the 10-GHz band is listed in the *ARRL Operating Manual*, where the band edges (10.0 to 10.5 GHz) are given and a note states that pulsed emissions are not permitted.

To illustrate the concept, Fig 23.19 shows a broadband receiver, capable of receiving 10.1 to 10.14 MHz. This bandwidth is well with the capabilities of much 10-GHz equipment. A band plan *for the repeater* is shown. Three 10-MHz-wide channels are provided for ATV (10.1 to 10.11, 10.11 to 10.12, and 10.12 to 10.13). Three additional data (nonpulsed) channels, each 3 MHz wide, are provided, and finally a 1-MHz-wide channel for multiple narrowband communications (10 kHz or less) channels are also shown. This 1-MHz channel would probably have its own "band plan."

It is in the latter area that local VHF and UHF repeaters would be linked to the 10-GHz system. Two of the 10-MHz channels are shown repeated by the broadband transmitter as well as two of the 3-MHz channels. Similarly, a number of narrow-band channels are repeated. Other channels are switched to an interarea broadband link.

The channel selection could be implemented by down conversion, filtering and up conversion. It would not be necessary to filter or separate each channel, since channel groups could be selected for various purposes. For example, a UHF ATV repeater to be repeated at 10 GHz would transmit to the repeater in one of the two channels shown for repeaters. If it were to be linked it would transmit to the 10-GHz repeater in the 10.120 to 10.130-GHz channel.

Implementation details would generally be quite close to those shown in the satellite transponders (section following), with the exception that in satellite service only one such transponder may be used. In a ground application several can be used. This would be termed *space diversity*. Since the antennas at these frequencies generally have relatively narrow beamwidths, several of these 10-GHz repeaters could be colocated with antennas facing different directions and the data linked internally.