Microwaves

Bob Atkins, KA1GT

MICROWAVE BASICS

This isn't the column I had originally planned for this month. Instead I've written in response to a number of letters from Amateurs who want some very basic information on microwaves. Because it's easy for me to forget that not everyone knows about the microwave bands, I'll devote column space this month to an introduction to microwaves. My own personal preference is towards weak signal work, so this may be reflected in my descriptions of microwave activity. However, other modes (like ATV, FM repeaters, and packet) can be found on the bands.

What are "microwaves?" As a working definition, consider microwaves to be electromagnetic waves with a frequency greater than 1000 MHz or a wavelength less than 30 cm. That defines the lower frequency limit, but how high in frequency do microwaves go? The answer to this question is somewhat nebulous; an upper limit would be somewhere around 300 GHz (300,000 MHz). Within this region there's a subdivision referred to as millimeter waves. It's the area between 30 and 300 GHz, where the wavelength is less than 1 cm. United States Amateurs have 11 bands allocated above 1 GHz, with a combined bandwidth of 23 GHz (23,000 MHz), so you can see that there's plenty of room! I'll define and describe these Amateur bands later. At this point, you just need to know that they exist and have an idea of their size.

Before dealing with any of the technical aspects of microwaves, it may be helpful to try to answer a question which has been posed to me quite frequently. What is the attraction of working on the microwave bands? This is a difficult question and probably has as many answers as there are active microwave Amateurs. The microwave bands provide the challenge of exploration. Many of the bands are sparsely populated; indeed some of them have never been worked at all! There's a real opportunity to be "first" on a band, make the first contact over a given path, discover a new mode of propagation, or make a real technological contribution to state-of-the-art operation. Even if you don't do any of these things, there's a sense of personal satisfaction and achievement in being one of the pioneers on the newly developing bands. The low population of the bands lends itself to other characteristics. For instance, there's no QRM, and in my opinion the overall operating standards are higher. Listening to some of the poor conduct on the HF bands is a distressing experience. I've never heard any discourtesy, deliberate interference, or other undesirable conduct on the microwave bands. The low population also encourages a sense of community and cooperation between those Amateurs who are on the microwave bands. It's in everyone's interest to help develop activity — even if it's just so there's someone to talk to on the air! In a way, microwave operation is a throwback to the very early days of ham radio — not in technology, but in spirit.

Now let's move on to some of the technical aspects of microwave operation and see how they differ from those found on the lower bands. Perhaps the most obvious difference is the shorter DX range. While many paths in excess of 1000 km have been worked, such DX is rare. I'll cover this in more detail later, but for now it's enough to know that range will be a few hundred kilometers. Such DX work uses antennas with high gain (>20 dBi), and hence a very narrow beamwidth. Consequently, you have to know where the DX is in order to point the antenna with sufficient accuracy to work it! As a result, a lot of microwave work is based on prearranged schedules, or relies on liaison at lower frequencies (often 144 MHz). Much of the activity on the microwave bands is concentrated during contests, local activity nights, or local nets. For example, the Pack Rats group in the Philadelphia area has a 1296-MHz net every Monday night at 9:30 p.m. on 1296.1 MHz.

The importance of a good QTH site is paramount on the microwave bands (especially at the higher frequencies); thus there's a lot of portable operation from mountaintops. As typical microwave TX power is low (maybe 1 watt), and antennas are small (a 3 or 4-foot parabolic dish on 10 GHz is about the practical limit), portable operation is quite convenient. **Photos A** and **B** show examples of portable operation on 3456 and 5670 MHz by members of the North Texas Microwave Society.

For those not interested in working DX, the microwave bands offer one other unique feature — bandwidth, and lots of it. For example, the 10-GHz band is 500 MHz wide and ideally suited for high speed digital data links which can rapidly use up bandwidth. Because microwave antennas are highly directional, and DX propagation is difficult, a number of high speed data links can use the same frequencies, even when they are close to each other geographically. Similar factors apply to other wide bandwidth modes. Who will be the first Amateur to transmit high speed digital HDTV signals on the air? One mode uniquely permitted on the microwave bands is pulse modulation. Though this mode is prohibited on all bands below 1000 MHz, it's allowed on all the microwave bands except for 1240 to 1300 MHz and 10 to 10.5 GHz

As I mentioned earlier, there are 11 Amateur microwave allocations. I'll take a look at each one and try to describe their characteristics. Some of these bands have full or partial ARRL-recommended band plans. In general, narrowband weak signal work takes place on frequencies related to harmonics of 1152 MHz (for historical reasons involving frequency multiplying).

- **1240 to 1300 MHz,** or the 23-cm band. This is the most populated

PHOTO A

N5JJZ/5 demonstrates portable operation on 5760 MHz.

PHOTO B

North Texas Microwave Society Expedition on 3456 MHz. Elevation is controlled by jacking up the rear of the van! WA5TNY is seen adjusting the dish.

microwave band, and the one most like the VHF/UHF bands in its operational characteristics. Novice operation is permitted between 1270 and 1295 MHz. Conventional vacuum tubes (2C39) can be used to generate power, and power levels of 100 watts aren't uncommon. Antennas are generally of the Yagi type (or loop Yagi where 1-wavelength loops replace the usual 1/2-wavelength elements like a multi-element quad). Antennas are quite small; a 25-element Yagi is a little over 6 feet long. Fixed station operation is common, and a well-equipped station can expect a DX range of several hundred kilometers under flat conditions. The California/Hawaii path has been worked on this band (3977 km) using modest power and antennas (N6CA's 100-watt, 44-element loop Yagi to KH6HME's 25-watt, 4 by 25-element Yagis). Under good conditions, distances of up to 100 km can be worked with power levels of less than 1 watt. The narrowband calling frequency is 1296.1 MHz. The ARRL band plan has allocations for repeaters, satellite uplinks, ATV, and digital communications, and there's activity on all these modes. Much commercially built equipment is available for this band — from complete multi-mode transceivers costing well over $1000, to low power transverter kits in the $140 price range.

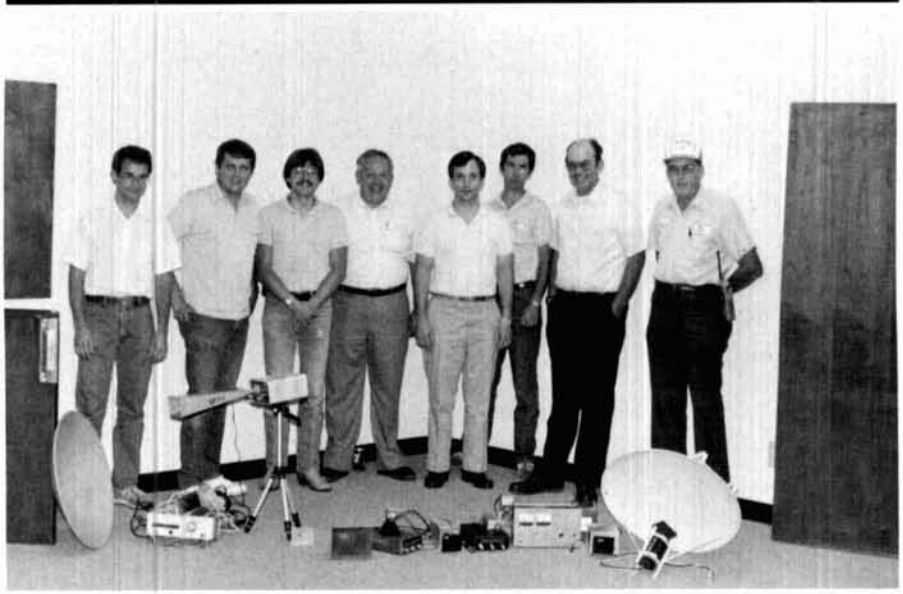
- **2300 to 2310 MHz and 2390 to 2450 MHz,** or the 13-cm band. Activity here is much lower than on 23 cm, though it's growing and quite well established in some areas (like North Texas and Philadelphia). Quite a lot of operation takes place from fixed stations. Power can still be generated with cheap vacuum tubes (2C39s, $10 surplus) at levels of 20 to 30 watts. Antennas are usually of the Yagi type, but some parabolic dishes are in use. Range is less than at 23 cm, but considerable distances can be worked with low power under good conditions (W8YIO's 30-mW, 8-foot dish to WA8TXT's 200-μW, 4-foot dish. There were strong signals at 135 km; the path could have been worked using 2-foot dishes). The narrowband calling frequency is 2304.1 MHz. Commercially built equipment is available. The mode S satellite downlink is in this band (2401 MHz).
- **3300 to 3500 MHz,** or the 9-cm band. Activity is very low, but growing slowly. Conventional vacuum tubes don't work well at these frequencies and power must be generated using solid-state devices or exotic vacuum tubes, like traveling wave tubes or klystrons. Parabolic dishes are the most common antennas. Much of the equipment is homebrew, though there are now some commercial transverter kits available. Some TVRO (satellite TV) equipment can be modified for use in this band, providing excellent performance at low cost. The narrowband calling frequency is 3456.1 MHz.
- **5650 to 5925 MHz,** or the 6-cm band. Activity here is very low. There are a few stations on the band with homebrew systems (often containing surplus commercial parts). Currently, there's no readily available commercial equipment for this band. The narrowband calling frequency is 5670.1 MHz.
- **10 to 10.5 GHz,** or the 3-cm band. Second only to the 23-cm band, this microwave band has one of the highest levels of activity. This band is popular because it's easy to get on using wideband equipment based on Gunn oscillators. A Gunn oscillator is a resonant cavity containing a Gunn diode. When a DC voltage (about 9 volts) is applied across the diode, oscillation occurs at the resonant frequency of the cavity. Power output is in the 10 to 100-mW range. Complete commercial wideband systems (Known as "Gunnplexers"™) are available for a few hundred dollars. A homebrew system can be built for a few tens of dollars and not much technical microwave knowledge is required. Antennas are usually parabolic dishes 1 to 3 feet in diameter. Any line-of-sight path can be worked using such equipment, but almost all obstructed paths require the presence of enhanced propagation modes (ducting) which occur infrequently. The world record of 1000+ km was made using such a wideband system. In addition to wideband systems, there are an increasing number of narrowband systems coming on the air which use conventional transverter techniques. This is in large part due to the availability of commercial (SSB electronics) transverter components (local oscillators, transmit and receive mixers). Kits are available for a few hundred dollars; built and tested units cost about double. Power output is in the 100 to 200-mW range, and this is enough to work many obstructed (non line-of-sight) paths of several hundred kilometers on a regular basis. Such paths would be difficult, if not impossible, to work using wideband equipment. Most of the operation is still done from portable stations on hilltops, but a number of stations are developing fixed station capabilities. Several stations have employed ATV and digital modes on this band. The

ARRL has a 10-GHz contest which takes place every year over two weekends in August and September. Last year the leading station (W6HHC) made 78 contacts with 17 different stations and a best DX of 266 km. Thirty-one stations made contacts in excess of 100 km. Oscar 9 carried a beacon on this band (10.470 GHz). The narrowband calling frequency is 10.361 GHz.

- **24 to 24.25 GHz,** or the 1.5-cm band. There isn't much regular operation on this band. The majority of activity involves Gunn oscillator-based systems, though some narrowband transverters have been built. This is the lowest frequency band at which attenuation by the atmosphere (oxygen and especially water vapor) is a significant factor in propagation, amounting to about 0.2 dB/km.
- **47 to 47.2 GHz.** This band has no alternative wavelength name. It's the lowest frequency Amateur millimeter wave allocation. Atmospheric attenuation is significant at about 0.4 dB/km. There is Amateur activity, but it's confined to one or two stations.
- **75.5 to 81 GHz.** This is the highest frequency band on which I am aware of Amateur activity. Atmospheric absorption amounts to about 0.4 dB/km.
- **119.98 to 120.02 GHz.** There's no known Amateur operation at this level. Atmospheric absorption is around 2 dB/km.
- **142 to 149 GHz.** No known Amateur operation — there's atmospheric absorption of around 2 dB/km.
- **241 to 250 GHz.** No known Amateur operation — atmospheric absorption is in excess of 5 dB/km.
- **Above 300 GHz.** This is the highest band (if it can be called that, as there is no upper limit). I know of no Amateur RF work in this region, but if you go up high enough in frequency this "band" includes lightwave (laser) communications, where there is activity.

Many of these bands are shared by radiolocation (radar) services and you must tolerate interference from them. In practice, this isn't a problem. There are also some nearby radio astronomy bands which are protected from Amateur interference.

PHOTO C



Members of the North Texas Microwave Society with their 10-GHz equipment assembled before the first weekend of an ARRL 10-GHz cumulative contest.

How do you get started on the microwave bands? Again, this question has no simple answer; much depends on the individual involved. First, and most important, I'd recommend joining a local group active on microwaves. I can't stress this point too strongly. The group not only provides help and encouragement, but also gives you a number of stations to work. **Photo C** shows members of the North Texas Microwave Society with their collection of 10-GHz equipment, ready for one leg of the ARRL 10-GHz contest. If a local microwave group doesn't exist, try to find a VHF/UHF group. You'll probably find some microwave knowledge and interest there, even if there's no activity. If you can't find either, try to find another ham interested in developing microwave capabilities. You can share knowledge, help each other with construction, and be certain of someone to work once you get your station built! What can you do if you really can't find any help? If all else fails, write to me and I'll try to put you in touch with someone in your area. If I don't know of anyone, I can put your call and address in this column with a plea for help. If that fails, you'll just have to change QTH! It's also important to read up on the subject. There are some good microwave books covering both theory and practice; I'll list a few at the end of this article.

Where should you start to work? I suggest either 23 cm or 3 cm. If you want to work from a fixed station, and you want to find the most activity, 23 cm is the band of choice. While the microwave characteristics of operation on the band make it somewhat different from lower frequencies, much of the equipment and propagation will still seem familiar to VHF/UHF operators. Activity is high enough to make random contacts possible, particularly in urban areas and during activity periods and contests. Most transverter systems use a 144-MHz IF, so a VHF transceiver or transverter is required. Commercial equipment is widely available and a lot of homebrew designs have been published. Check out the "UHF and Microwave Equipment" chapter of a recent *ARRL Handbook* for ideas. Of course it's not necessary to start out with a complete transverter system. Operation using a receive converter and tripler from 432 MHz is quite possible using CW and FM. It's not as convenient as a transverter, but is cheaper, easier to build, and quite capable of yielding equal results. A low power 432 to 1296-MHz tripler can be built using 1N914 diodes (10 cents each!) and, despite a power output of less then 1 watt, I have personally used such a tripler to work distances of >50 km.

On the other hand, if you like the idea of hilltop/portable operation, and want to try out a band with very different characteristics and equipment from the

lower bands, then 3 cm is the band of choice. You won't make any random contacts on this band, so you must be in contact with at least one other interested Amateur. There are two main modes of operation on 10 GHz. First, there are wideband systems with IF bandwidths of 50 kHz or more, which use free running cavity-stabilized Gunn oscillators and usually operate using FM. Second, there are narrowband systems with IF bandwidths of 3 kHz and less, which use frequency multiplication and mixing from lower frequency crystal-controlled sources and operate using SSB and CW. For low cost experimentation, ATV, or digital operation, the wideband Gunnplexer route is best. You can purchase a complete Gunn oscillator-based transceiver from a commercial source for a few hundred dollars. Alternatively, you can build a basic Gunn oscillator/mixer system from a few pieces of waveguide and a couple of diodes for a total cost of around $20. By combining this equipment with a simple power supply and the IF strip from an FM radio (or even an FM radio itself), you can construct a complete transceiver. Some Amateurs are working on ways to convert surplus Gunn oscillator-based microwave radar detectors, automatic door openers, and intruder alarms to Amateur use at low cost. For serious DX and weak signal work under all conditions, narrowband operation is preferred, though it's more expensive and requires a little more microwave knowledge. Narrowband operation will also make possible many more paths than will wideband operation. Wideband systems are quite capable of DX operation under good propagation conditions. (In fact, the world and United States DX records are held by Amateurs using wideband equipment.)

Equipment is available from a number of suppliers. Take a look through this issue of *Ham Radio*; I'm sure you'll find advertisements for companies who specialize in equipment for the microwave bands. All should be able to give you information on microwave equipment, and some may even be able to help you find active microwave stations in your area. If you have trouble finding a specific piece of equipment, I may be able to help. However, it's hard to keep up to date, so check out the ads in the Amateur Radio publications first.

I hope this information is helpful to newcomers who are interested in the microwave bands. There isn't room to print any detailed technical information about how to build simple microwave equipment this month. I hope to return to this topic in the future and try to present some simple projects.

Recommended reading

The following publications are recommended for those who want to learn more about microwaves. Some of these books are available from the HAM RADIO Bookstore.

The RSGB VHF/UHF Manual. Lots of information on theoretical and practical aspects of VHF/UHF and microwave operation. Recommended to anyone interested in these bands. (Available from the HAM RADIO Bookstore for $29.95 plus $3.75 shipping and handling.)

The Gunnplexer Cookbook, by Bob Richardson, published by the Ham Radio Publishing Group. A practical book which describes a large number of projects based on the Microwave Associates Gunnplexer system for 10 GHz. A good start for the newcomer to 10-GHz wideband operation. (Out of print.)

The RSGB Microwave Manual. I still haven't seen this one, but on the basis of its authorship it should be a valuable reference. (Available from the HAM RADIO Bookstore for $35 plus $3.75 shipping and handling.)

10 GHz — A Constructional Project, by Chuck Houghton, published by the San Diego Microwave Group and priced at $15. A collection of notes mostly relating to wideband operation on 10 GHz and some information relevant to narrowband work. Lots of detailed construction information with a little bit of theory. Includes test equipment, use of converted intruder alarms, antennas, homebrew and commercial Gunn oscillators, and more. Some components (IF boards, Gunn diodes, etc.) are also available from this group. Contact Chuck, WB6IGP, at 6345 Badger Lake, San Diego, California 92119.

The RSGB Microwave Newsletter Technical Collection. A collection of technical items from the RSGB microwave newsletter. Covers practical design information for the bands 1296 MHz to 24 GHz. Includes information on oscillator sources, antennas, filter design and test equipment. (Out of print.)

The ARRL also publishes a series of conference proceedings from the Central States VHF Society, Microwave Update, and Mid-Atlantic States VHF Conferences. These publications cover all aspects of operation, theory, and practice on the bands from 50 MHz to lightwave. A good way to keep up with the state-of-the-art technical developments by those in the forefront of VHF/UHF and microwave work. Some, but certainly not all, of the material may be a bit advanced for absolute beginners. (Available from the HAM RADIO Bookstore. Check current book flyer and advertisements in this issue for prices.)

And, of course, back issues of *Ham Radio*. Check out the 5-year cumulative index which appeared in the December 1989 issue. You might also want to read some of the "New Frontier" columns which appeared in *QST* from 1980 to 1989.

Microwave news

As I've mentioned before, microwave operation often takes place on local nets so operators can have a good idea of when and where they'll find activity. WD4MBK has sent along information on a new 1296-MHz net in the Southeast. Dexter McIntyre, WA4ZIA, of Stanfield, North Carolina, has started a net which meets on 1296.090 MHz at 9:30 p.m. every Wednesday evening. The net is held in conjunction with the East Coast 70-cm net which meets on 432.090 MHz at 9:00 p.m., also on Wednesday evenings. On the first night of the 1296-MHz net, there were seven check-ins from five states (Georgia, Florida, Tennessee, South Carolina, and North Carolina). The best DX was a 500-mile contact between W4ODW and WA4ZIA. Stations interested in participating in the 1296-MHz net can check into the earlier 432-MHz net, where net control (WD4MBK) will take a list which will be passed on to the 1296-MHz net controller (WA4ZIA). At 9:30, WA4ZIA will call and listen on 1296.090, while listening simultaneously on 432.110 MHz for stations who wish to join the 1296-MHz net. Stations further to the north (Virginia, Maryland, New Jersey, and Pennsylvania) should look for K4CAW (North Carolina). He will call and listen on 1296.090 at 9:30 p.m. for check-ins from the north.

WA4ZIA has also become operational on 3456 MHz with 5 watts to a W3HQT loop Yagi. To eliminate feedline losses, the 3456 transverter and power amplifier are mounted at the antenna on top of his tower. In his first week on the band, he worked W4OJK

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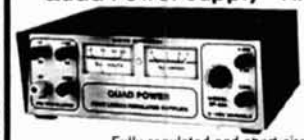

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Microwaves and no-code

While it's often difficult to be topical in a column written so far in advance of publication, I'm quite sure that the code versus no-code issue will still be under debate when you read this. On February 16th, the FCC issued a notice of proposed rule making (NPRM) in their docket number 90-55. If you haven't read this document, and are concerned with the future of ham radio, please do so. Basically, it calls for dropping the Novice and Technician class licenses and establishing a Communicator no-code license entitling the holder to all privileges on 222 MHz and above. While the debate may be fierce (there are those who argue with a fervor usually reserved for politics and religion), it seems that some kind of no-code license will be the outcome. You may ask what this has to do with microwaves. Well, all the no-code proposals allow — in fact, are actually targeted towards — newcomers to the bands where more activity is badly needed. Much of the fine work done in the UK on the microwave bands has been through the efforts of Amateurs there who hold no-code licenses. (Indeed, my first license was a UK no-code, though my contributions to microwave activity were negligible!) The microwave bands are being eyed increasingly by commercial interests as technology makes their use more practical. If we don't occupy the bands we'll have little grounds for objection if we start to lose them. If a no-code license can increase microwave activity, then I welcome it. Even if it doesn't, I don't think a limited no-code license will do harm.

If you feel strongly on the issue of a no-code license, I urge you to send your comments to the FCC (but do read the text of their proposal first). I favor the idea of the Communicator license, but I think dropping the Novice and Technician classes, with their low speed CW requirements, would be a mistake. Whatever your views, make them known to the FCC, and if the eventual outcome is a new group of no-code Amateurs, then let's make sure we welcome them to ham radio without prejudice and encourage them to join us on the microwave bands (and learn CW!).

Finally, thanks again to all of those who have taken the time to write. The direction and content of this column depends on your letters, so keep them coming. If you send photos, please be sure to include all the information about the photo on the back. Black and white prints are preferred, but color is okay. Next month I plan to discuss tropospheric scatter propagation on the microwave bands.