The HF Bands – For HF Newcomers

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The HF ham bands can be mysterious. Some work at night, some during the day. Some seem to be good for long distance contacts while some are better for nearby contacts. Even worse, they change tremendously from hour to hour and day to day.

Communications beyond a few miles on the HF bands occurs because of the Ionosphere. That is part of the Earth's atmosphere from roughly 35 miles to about 300 miles up. It is called the Ionosphere because at those elevations, radiation from the sun, primarily ultraviolet, ionizes atmospheric molecules. That ionization process absorbs most of the harmful solar radiation, making life on the surface of the Earth possible. It also causes the atmosphere to reflect radio signals.

The actual operation of the Ionosphere that allows us to communicate over long distances is very complex. At the bottom, air pressure is about a thousandth of surface normal. At the top, it is about eight orders of magnitude lower. Different wavelengths and kinds of solar radiation effect different heights. By bouncing radio signals off the Ionosphere, several main regions or layers within the Ionosphere have been identified. The layers we care about are labeled, from lowest to highest, D, E, and F.

The D layer, at about 35 to 50 miles up, is strongest during the daylight hours and is primarily an absorber of radio signals. It tends to absorb lower frequencies more than higher frequencies. The D layer is why 160 and 80 meters don't work very well during the day.

The E layer, at about 50 to 100 miles up, is a wild card in radio propagation. It is sometimes present and sometimes not. Sometimes it absorbs signals. Mostly, though, it reflects. Sometimes is reflects very well, even up into the VHF region.

The F layer is what does the real work of bouncing our signals around the country and around the planet. Its operation is primarily that of a reflector. Through extensive study of this layer with radio soundings, two main regions within it have been identified and labeled F1 and F2. The F1 layer extends from about 100 miles to 130 miles up and exists mostly during the daylight hours. The F2 layer extends from about 130 miles to about 300 miles up and, because of the very low atmospheric density, experiences very slow ion recombination so remains largely intact through the night.

As I said above, the operation of the Ionosphere on radio signals is very complex. The simple explanation above does not do it justice. It will, however, do OK as a general introductory description. For the most part, we don't really care how the Ionosphere operates as long as we can figure out roughly what bands and what times it will allow us to operate.

The Sun Spot Cycle

Now we come to an important aspect of HF radio operation: the sunspot cycle. Above we learned that HF radio signals bounce off the ionosphere because the sun ionizes air molecules at very high altitudes. Obviously if there is more solar radiation there will be more ionization. The more ionization we have, the better our signals bounce. It turns out that the radiation level from the sun follows the 11-year sunspot cycle. In general, the more spots we see on the sun, the more ionization we notice.

Now, in early 2007, we are just past the bottom of the sunspot cycle. Radio propagation on the upper HF ham bands is poor. By the next sunspot peak in about 2011 or 2012, the upper bands will be hopping with activity, with worldwide communications on 10 meters possible with low power and modest antennas. That is something most of us hams are looking forward to. Between now and then, we will see a slow, gradual rise in sunspot count and upper HF band performance. However, things will not be all peaches and cream when we reach the sunspot peak.

The sunspot peak is a turbulent time on the sun. Solar flares and X-ray bursts occur disturbing the upper atmosphere and disrupting HF operation. Day to day operation on the ham bands can vary widely. In general though, the higher the sunspot count, the better the upper HF bands operate.

Sunspot Count and Solar Flux

You will encounter two different measures of solar activity. The first is the visual count of sunspots. The second is the 10.7 cm (2800 MHz) solar microwave radiation level, called Solar Flux Index. The two values roughly follow each other, though on different numeric scales, but the Solar Flux Index tends to provide a more immediate and direct indication the effect of the sun on the Ionosphere. The current Solar Flux Index (SFI) is available from several sources on the Internet. It is also available in a voice broadcast on WWV at 18 and 45 minutes past each hour.

In general, SFI values above 200 are considered high, indicating bands up through 10 meters should provide long openings. SFI values below about 100 are considered low and typically mean that the higher bands will not be as good. As the SFI rises from 100 towards 200, upper band operation gradually improves. Openings become common during the day on 10 meters by the time the SFI reaches 180.

Night and Day

Ok, you have probably already realized that since it is primarily the sun that we care about for our use of the Ionosphere, night and day must matter. Each layer of the Ionosphere reacts to the diurnal changes differently. Since the air pressure is greater at lower altitudes, ions tend to recombine quicker there. That means that D layer absorption drops off rapidly as the sun sets and doesn't build up again until sunrise.

F layer ionization drops off at night. The lower F1 layer drops off quickly. The high F2 layer remains intact through most of the night.

The E layer seems to do its own thing. Its ability to reflect radio signals usually peaks at midday but occasionally it will provide nighttime communications opportunities. In general, we pay relatively little attention to it, enjoying its services when it helps, cussing it when it helps too much and reflects so well that it acts as a screen between you and the longer distance F layers.

In general, the lower bands, 80 and 160 meters are best at night because of daytime D layer absorption. 30 and 40 meters typically work both night and day but daytime distances are limited because greater distances require lower propagation angles, which, in turn, mean longer paths through the D layer. 15, 17, and 20 meters suffer much less D layer absorption problems but require higher levels of ionization in the F layers so work best during the day. 10 and 12 meters are almost exclusively daytime bands except for those years at the top of the sunspot cycle.

Summer and Winter

OK, if night and day makes a difference in HF propagation, what about summer and winter? Of course the seasons make a difference. Wintertime enhances the lower frequency nighttime bands and reduces operating times on the higher frequency daytime bands. The longer days in summer reduce the operating times for the lower frequency nighttime bands.

Actually, the summertime is when the 160 meter and 80 meters bands can be nearly unusable. While the shorter days have an obvious effect, the real problem is lightning storms. Summer is the time of year when thunderstorm activity is greatest. Lightning creates radio noise that is reflected off the Ionosphere just like regular radio transmissions. Some weeks, in the spring through early autumn storm season, thunderstorm activity within one or two Ionospheric hops will be continuous.

The good news about thunderstorm activity is that it drops off during the winter allowing good 160 and 80 meter operating conditions. Also, the amount of radio noise generated by thunderstorms decreases with frequency so that the higher daytime bands are relatively free of thunderstorm noise. That is, of course, unless the storm is close by.

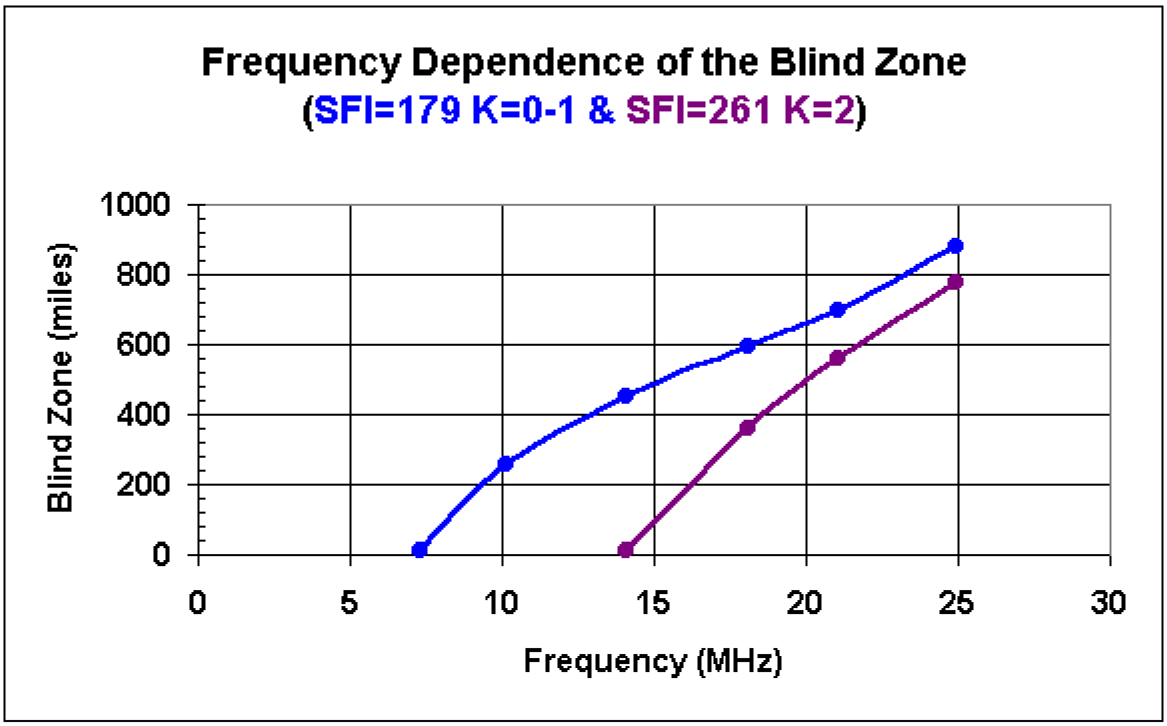
In general, 160, 80, 60, 40, and 30 meters are at their best during the winter. 20, 17, 15, 12, and 10 meters are at their best during the summer. The combination of day/night, summer/winter, and sunspot cycle variations keeps HF operation interesting. You never know for sure from moment to moment what you are going to encounter when you tune across the different ham bands.

The Skip Zone or Blind Zone

Another point worth noting is something called the Skip Zone. The term 'skip' has been misused so much that some folks are beginning to call this the Blind Zone. This is the result of another characteristic of the Ionosphere. There is something called the Critical Frequency, which is a frequency above which a signal sent straight up will not be reflected. In general, the higher ionization, the higher this vertical incidence critical frequency is.

The skip zone is effectively a hole in the Ionospheric reflection over your station. The diameter of that hole increases with frequency. Fortunately though, just like with light reflecting off a pool of water, the Ionosphere becomes more reflective as the incidence angle becomes less.

What this means is that the 20 meter band and the bands above it do not typically support local communications. Stations within the skip zone cannot be contacted via direct Ionospheric reflection. The chart below shows typical Skip Zone distances for both midway along the rise of the sunspot cycle and another near the top.



At the bottom of the sunspot cycle, skip zones are common on 40 meters at night and can occur even on 80 meters.

HPF, MUF, and LUF

On an hour by hour and day by day basis, we are interested in values known as Highest Possible Frequency (HPF), Maximum Useable Frequency (MUF), and Lowest Useable Frequency (LUF) for a given radio path between two locations. These values give us an indication of what frequencies and times we are most likely to have successful communications.

HPF is the highest frequency expected to be supported for a given path at a given time of day. Frequencies higher than the HPF will simply pass through the Ionosphere because of insufficient ionization. MUF is a frequency that is predicted to have a 50% probability of being below the HPF for that same time of day. LUF is determined primarily by D layer absorption.

Signal levels are generally best on frequencies at or just below the MUF. Signal levels drop off to useless as the LUF is approached. The MUF varies from predicted values quite a lot from day to day. An optimum working frequency choice for reliable communications is normally about 85% of the MUF as long as that is still above the LUF.

The ARRL provides on-line plots of HPF, MUF, and LUF predictions on a month-by-month basis. These plots may be found on the following web page:

http://www.arrl.org/qst/propcharts/

An example of these plots may be found on the last page of this document.

The HF Bands

The 10 ham High Frequency bands (actually 9 HF and 1 MF band since 160 meters is considered part of the Medium Frequency part of the radio spectrum) were chosen to take advantage of the varying propagation characteristics of the Ionosphere. They cover 16 to 1 frequency range from 1.8 MHz to 29.7 MHz. Each of the bands has unique propagation characteristics. Each could be a study unto itself. We don't need that here. Instead I will simplify and generalize.

160 Meters:

160 meters is primarily a nighttime regional band. Nighttime range is usually very good from next door out to about 500 miles when full size horizontal antennas are used. Worldwide DX is possible on this band, but tall vertical antennas with extensive ground radials for transmitting and long, low noise beverage antennas for receiving are necessary. Atmospheric noise from lightning can make this band nearly useless during the summer thunderstorm season.

80 Meters:

80 meters is again primarily a regional band though nighttime coverage often extends out to 1500 miles. Morning and afternoon operation out to about 200 miles is not uncommon. Worldwide nighttime DX is possible on this band and much more likely accessible than 160 meters because of the smaller antennas required. 80 meters suffers from high summer lightning noise but somewhat less so than 160 meters.

60 Meters:

60 meters provides a mix of the characteristics 80 meters and 40 meters. It has better daytime coverage than 80 meters. Due to power limits, practical operation even at night is typically limited to about 750 miles though transcontinental DX operation has been achieved.

40 Meters:

40 meters is a daytime regional band with good coverage out to about 300 miles with medium height dipole antennas. Nighttime coverage is often worldwide though this has turned out to be more of a problem than an advantage. Part of the 40 meter ham band is a short wave broadcast band in most other parts of the world. It is very difficult to find an empty spot to operate when band conditions are conducive to good DX operation. Summer night lightning noise is a problem on this band but not nearly as much as the lower bands.

30 Meters:

30 meters typically provides coverage out to about 1500 miles during the day but may have a skip zone preventing contacts closer than about 100 miles or so. Nighttime coverage remains good with transcontinental contacts common. The nighttime skip zone expands but this sometimes helps by excluding noise from regional lightning storms.

20 Meters:

20 meters is the king of the DX bands. It is usually below the MUF during the daylight hours and suffers less D layer absorption than lower bands. It usually has a skip zone extending out at least 300 miles, with 500 miles not uncommon, making regional operation impractical.

20 meters operation is profoundly effected by the sunspot count. At the peak of the sunspot cycle, this band can remain open to worldwide contacts 24 hours a day. At the bottom, it may open only during daylight hours and even then signal levels can be low. Evening contacts to the west are especially good since D layer ion recombination happens quickly as the sun angle decreases while the F layer ionization decreases much less rapidly. A similar but less noticeable effect happens with eastward contacts in the morning.

17 Meters:

17 is a lower keyed version of 20 meters. Being a higher frequency, it doesn't open as early as 20 meters and closes sooner but still provides plenty of DX and rag chew opportunities. The skip zone on 17 meters is somewhat larger than for 20 meters but good signals are generally available from about 500 miles out and farther. 30, 17, and 12 meters are known as the WARC bands and are protected by informal international agreement from contest operation. (WARC stands for World Administrative Radio Conference or some such thing. It is where governments make international agreements on communications issues. 30, 17, and 12 were awarded to amateur radio at one the WARC sessions.) Rag chew operation is common but Dxers will also use the band to

take advantage of the lower crowding. 17 meters is great for contacts to the east in the morning hours and to the west in the afternoon hours.

15 Meters:

15 meters continues the trend seen in the 20 and 17 meter bands. It opens later than 17 meters and closes sooner. It is common for 15 meters to be nearly dead, even during the daylight hours, for two or three years around the bottom of the sunspot cycle. As the sunspot count rises toward the next peak, 15 meters will begin opening up during the day. Being higher in frequency, it suffers even less D layer absorption than 20 meters so signal strengths tend to be good for open paths.

15 meters is large band, providing plenty of room for Dxers and Rag Chewers to coexist. The skip zone on this band is somewhat larger than what is seen on 17 meters so contacts with distant locations are far more likely than contacts with nearby locations. As with the other daytime bands, contacts to the east in the morning and west in the evening are typically improved over mid-day operation.

12 Meters:

12 meters is a combination of 15 meter and 10 meter characteristics. Being a WARC band, it is free of contest operation. It also suffers little interference from foreign broadcasters and other commercial radio services. 12 meters provides good DX opportunities during the high part of the sunspot cycle. Operation on this band tends to be fairly relaxed with rag chewing much more common than DX pileups.

10 Meters:

10 meters is especially interesting. It lies on the threshold of VHF. When this band opens up, even low powered radios and modest antennas can make world wide DX contacts. While the 10 meter F layer skip zone is relatively large, sometimes not allowing contacts closer than about 1000 miles, the E layer will sometimes provide contacts to much closer locations. The E layer is much lower than the F layer so reflections from the E layer hit the ground closer.

For 10 meters to perform up to its maximum potential, the sunspot count must be high. You can count on some exciting activity on this band starting two or three years from now.

So what band should I use?

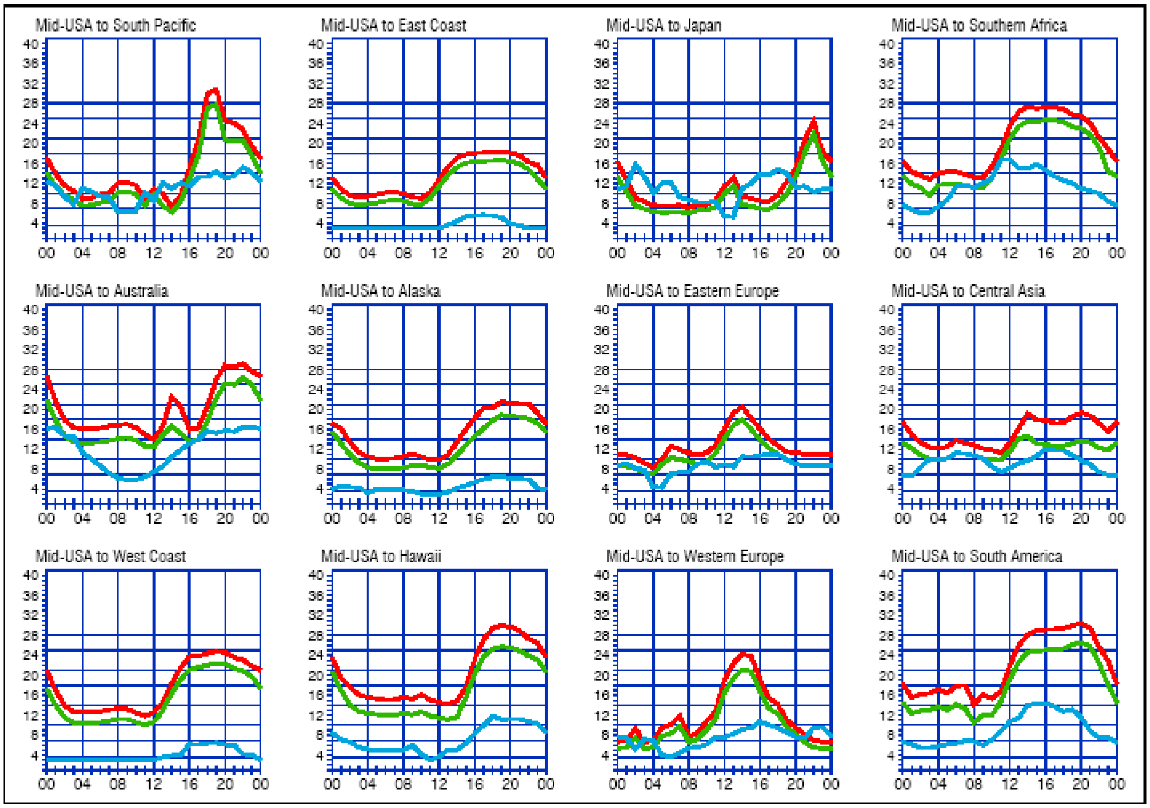
As was described above, each of the 10 HF/MF bands has its own individual characteristics. Each has advantages and disadvantages. In the lower part of the sunspot cycle, ham activity is most often found on 17 meters and lower in frequency. While the 15 through 10 meter bands will have occasional short openings to random locations, they are infrequent enough that little attention is paid to them until the sunspot count increases.

As the sunspot cycle improves, ham activity will gradually shift upward in frequency. With more consistent band openings, activity will increase providing more opportunities for contacts on the higher bands. Along with the improvement in the upper bands from increased solar radiation, lower bands experience greater D layer absorption, decreasing their communications effectiveness somewhat. Even with the increased absorption, though, the lower bands remain very useful for regional communications and rag chewing.

At the bottom of the sunspot cycle, as we are now, a combination operation of 40 meters during the day and 80 meters at night give the highest likelihood of making contacts. 160 meters is also a good choice for nighttime operation for those that have room for a 230 foot long dipole. 30 meters provides an interesting, uncrowded band to enjoy casual CW operation. 20 meters and 17 meters provide plenty of opportunities for both rag chew and DX contacts but primarily during the daylight hours.

For those interesting in making their first DX contacts, 20 and 17 meters are the best bet. DX operation is possible on all bands but is more easily achieved on 20 meters and above. Of course, as the sunspot cycle improves, gradually 15 meters, and then 12 and 10 meters will begin opening up.

The great thing about the HF/MF ham bands is that there is enough variety in characteristics to keep operation interesting. Enjoy the adventure of exploring them.



When are the bands open? These charts, generated using CAPman, show probabilities for average HF propagation in the month of **February 2007** for the paths indicated. The horizontal axes show Coordinated Universal Time (UTC), and the vertical axes frequency in MHz. On 10% of the days of this period, the highest frequencies propagated will be at least as high as the upper red curves (HPF, highest possible frequency) and on 50% of the days they will be at least as high as the green curves (MUF, classical maximum usable frequency). The blue curves show the lowest usable frequency (LUF) for a 1500-W CW transmitter. For SSB or a lower transmitter power, the LUF will be somewhat higher than the blue curves indicate. See Oct 1994 *QST*, pp 27-30, and Feb 1995 *QST*, pp 34-36, for more details. The predictions assume an observed 2800-MHz solar flux value of 73. This is a Very Low level of solar activity. See the detailed propagation tables on *The ARRL Antenna Book CD-ROM*.

Example ARRL propagation charts for February, 2007
http://www.arrl.org/qst/propcharts/

Radio propagation

From Wikipedia, the free encyclopedia

Radio propagation is the behavior of radio waves when they are transmitted, or propagated from one point on the Earth to another, or into various parts of the atmosphere.[1] As a form of electromagnetic radiation, like light waves, radio waves are affected by the phenomena of reflection, refraction, diffraction, absorption, polarization and scattering.[2]

Radio propagation is affected by the daily changes of water vapor in the troposphere and ionization in the upper atmosphere, due to the Sun. Understanding the effects of varying conditions on radio propagation has many practical applications, from choosing frequencies for international shortwave broadcasters, to designing reliable mobile telephone systems, to radio navigation, to operation of radar systems.

Radio propagation is also affected by several other factors determined by its path from point to point. This path can be a direct line of sight path or an over-the-horizon path aided by refraction in the ionosphere, which is a region between approximately 60 and 600 km.[3] Factors influencing ionospheric radio signal propagation can include sporadic-E, spread-F, solar flares, geomagnetic storms, ionospheric layer tilts, and solar proton events.

Radio waves at different frequencies propagate in different ways. At extra low frequencies (ELF) and very low frequencies the wavelength is very much larger than the separation between the earth's surface and the D layer of the ionosphere, so electromagnetic waves may propagate in this region as a waveguide. Indeed, for frequencies below 20 kHz, the wave propagates as a single waveguide mode with a horizontal magnetic field and vertical electric field.[4] The interaction of radio waves with the ionized regions of the atmosphere makes radio propagation more complex to predict and analyze than in free space. Ionospheric radio propagation has a strong connection to space weather. A sudden ionospheric disturbance or shortwave fadeout is observed when the x-rays associated with a solar flare ionize the ionospheric D-region. Enhanced ionization in that region increases the absorption of radio signals passing through it. During the strongest solar x-ray flares, complete absorption of virtually all ionospherically propagated radio signals in the sunlit hemisphere can occur. These solar flares can disrupt HF radio propagation and affect GPS accuracy.

Since radio propagation is not fully predictable, such services as emergency locator transmitters, in-flight communication with ocean-crossing aircraft, and some television broadcasting have been moved to communications satellites. A satellite link, though expensive, can offer highly predictable and stable line of sight coverage of a given area.

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Free space propagation

In free space, all electromagnetic waves (radio, light, X-rays, etc.) obey the inverse-square law which states that the power density of an electromagnetic wave is proportional to the inverse of the square of the distance from a point source[5] or:

$$\rho_P \propto \frac{1}{r^2}.$$

Doubling the distance from a transmitter means that the power density of the radiated wave at that new location is reduced to one-quarter of its previous value.

The power density per surface unit is proportional to the product of the electric and magnetic field strengths. Thus, doubling the propagation path distance from the transmitter reduces each of their received field strengths over a free-space path by one-half.

Modes

Radio frequencies and their primary mode of propagation

Band		Frequency	Wavelength	Propagation via
ELF	Extremely Low Frequency	3–30 Hz	10,000-100,000 km	
SLF	Super Low Frequency	30–300 Hz	10,000-1,000 km	
ULF	Ultra Low Frequency	0.3–3 kHz	1,000–100 km	
VLF	Very Low Frequency	3–30 kHz	100–10 km	Guided between the earth and the ionosphere.
LF	Low Frequency	30–300 kHz	10–1 km	Guided between the earth and the D layer of the ionosphere. Surface waves.
MF	Medium Frequency	300–3000 kHz	1000–100 m	Surface waves. E, F layer ionospheric refraction at night, when D layer absorption weakens.
HF	High Frequency (Short Wave)	3–30 MHz	100–10 m	E layer ionospheric refraction. F1, F2 layer ionospheric refraction.
VHF	Very High Frequency	30–300 MHz	10–1 m	Infrequent E ionospheric (E_s) refraction. Uncommonly F2 layer ionospheric refraction during high sunspot activity up to 50 MHz and rarely to 80 MHz. Generally direct wave. Sometimes tropospheric ducting.
UHF	Ultra High Frequency	300–3000 MHz	100–10 cm	Direct wave. Sometimes tropospheric ducting.
SHF	Super High Frequency	3–30 GHz	10–1 cm	Direct wave.
EHF	Extremely High Frequency	30–300 GHz	10–1 mm	Direct wave limited by absorption.
THF	Tremendously High frequency	0.3–3 THz	1–0.1 mm	

Surface modes (groundwave)

Lower frequencies (between 30 and 3,000 kHz) have the property of following the curvature of the earth via groundwave propagation in the majority of occurrences.

In this mode the radio wave propagates by interacting with the semi-conductive surface of the earth. The wave "clings" to the surface and thus follows the curvature of the earth. Vertical polarization is used to alleviate short circuiting the electric field through the conductivity of the ground. Since the ground is not a perfect electrical conductor, ground waves are attenuated rapidly as they follow the earth's surface. Attenuation is proportional to the frequency making this mode mainly useful for LF and VLF frequencies (see also Earth-ionosphere waveguide).

Today LF and VLF are mostly used for time signals, and for military communications, especially one-way transmissions to ships and submarines, although radio amateurs have an allocation at 137 kHz in some parts of the world. Radio broadcasting using surface wave propagation uses the higher portion of the LF range in Europe, Africa and the Middle East.

Early commercial and professional radio services relied exclusively on long wave, low frequencies and ground-wave propagation. To prevent interference with these services, amateur and experimental transmitters were restricted to the higher (HF) frequencies, felt to be useless since their ground-wave range was limited. Upon discovery of the other propagation modes possible at medium wave and short wave frequencies, the advantages of HF for commercial and military purposes became apparent. Amateur experimentation was then confined only to authorized frequency segments in that range.[6]

Direct modes (line-of-sight)

Line-of-sight is the direct propagation of radio waves between antennas that are visible to each other. This is probably the most common of the radio propagation modes at VHF and higher frequencies. Because radio signals can travel through many non-metallic objects, radio can be picked up through walls. This is still line-of-sight propagation. Examples would include propagation between a satellite and a ground antenna or reception of television signals from a local TV transmitter.

Ground plane reflection effects are an important factor in VHF line of sight propagation. The interference between the direct beam line-of-sight and the ground reflected beam often leads to an effective inverse-fourth-power ($1/\text{distance}^4$) law for ground-plane limited radiation. [Need reference to inverse-fourth-power law + ground plane. Drawings may clarify]

Ionospheric modes (skywave)

Skywave propagation, also referred to as skip, is any of the modes that rely on refraction of radio waves in the ionosphere, which is made up of one or more ionized layers in the upper atmosphere. F2-layer is the most important ionospheric layer for long-distance, multiple-hop HF propagation, though F1, E, and D-layers also play significant roles. The D-layer, when present during sunlight periods, causes significant amount of signal loss, as does the E-layer whose maximum usable frequency can rise to 4 MHz and above and thus block higher frequency signals from reaching the F2-layer. The layers, or more appropriately "regions", are directly affected by the sun on a daily diurnal cycle, a seasonal cycle and the 11-year sunspot cycle and determine the utility of these modes. During solar maxima, or sunspot highs and peaks, the whole HF range up to 30 MHz can be used usually around the clock and F2 propagation up to 50 MHz is observed frequently depending upon daily solar flux 10.7cm radiation values. During solar minima, or minimum sunspot counts down to zero, propagation of frequencies above 15 MHz is generally unavailable.

Although the claim is commonly made that two-way HF propagation along a given path is reciprocal, that is, if the signal from location A reaches location B at a good strength, the signal from location B will be similar at station A because the same path is traversed in both directions. However, the ionosphere is far too complex and constantly changing to support the reciprocity theorem. The path is never exactly the same in both directions.[7]

In brief, conditions at the two terminii of a path generally cause dissimilar polarization shifts, dissimilar splits into ordinary rays and extraordinary or *Pedersen rays* which are erratic and impossibly identical or similar due to variations in ionization density, shifting zenith angles, effects of the earth's magnetic DIPOLE contours, antenna radiation patterns, ground conditions and other variables.

Forecasting of skywave modes is of considerable interest to amateur radio operators and commercial marine and aircraft communications, and also to shortwave broadcasters. Real-time propagation can be assessed by listening for transmissions from specific beacon transmitters.

Meteor scattering

Meteor scattering relies on reflecting radio waves off the intensely ionized columns of air generated by meteors. While this mode is very short duration, often only from a fraction of second to couple of seconds per event, digital Meteor burst communications allows remote stations to communicate to a station that may be hundreds of miles up to over 1,000 miles (1,600 km) away, without the expense required for a satellite link. This mode is most generally useful on VHF frequencies between 30 and 250 MHz.

Auroral backscatter

Intense columns of Auroral ionization at 100 km altitudes within the auroral oval backscatter radio waves, perhaps most notably on HF and VHF. Backscatter is angle-sensitive—incident ray vs. magnetic field line of the column must be very close to right-angle. Random motions of electrons spiraling around the field lines create a Doppler-spread that broadens the spectra of the emission to more or less noise-like—depending on how high radio frequency is used. The radio-auroras are observed mostly at high latitudes and rarely extend down to middle latitudes. The occurrence of radio-auroras depends on solar activity (flares, coronal holes, CMEs) and annually the events are more numerous during solar cycle maxima. Radio aurora includes the so-called afternoon radio aurora which produces stronger but more distorted signals and after the Harang-minima, the late-night radio aurora (sub-storming phase) returns with variable signal strength and lesser doppler spread. The propagation range for this predominantly back-scatter mode extends up to about 2000 km in east-west plane, but strongest signals are observed most frequently from the north at nearby sites on same latitudes.

Rarely, a strong radio-aurora is followed by Auroral-E, which resembles both propagation types in some ways.

Sporadic-E propagation

Sporadic E (Es) propagation can be observed on HF and VHF bands.[8] It must not be confused with ordinary HF E-layer propagation. Sporadic-E at mid-latitudes occurs mostly during summer season, from May to August in the northern hemisphere and from November to February in the southern hemisphere. There is no single cause for this mysterious propagation mode. The reflection takes place in a thin sheet of ionisation around 90 km height. The ionisation patches drift westwards at speeds of few hundred km per hour. There is a weak periodicity noted during the season and typically Es is observed on 1 to 3 successive days and remains absent for a few days to reoccur again. Es do not occur during small hours; the events usually begin at dawn, and there is a peak in the afternoon and a second peak in the evening.[9] Es propagation is usually gone by local midnight.

Observation of radio propagation beacons operating around 28.2 MHz, 50 MHz and 70 MHz, indicates that maximum observed frequency (MOF) for Es is found to be lurking around 30 MHz on most days during the summer season, but sometimes MOF may shoot up to 100 MHz or even more in ten minutes to decline slowly during the next few hours. The peak-phase includes oscillation of MOF with periodicity of approximately 5...10 minutes. The propagation range for Es single-hop is typically 1000 to 2000 km, but with multi-hop, double range is observed. The signals are very strong but also with slow deep fading.

Tropospheric modes

Tropospheric scattering

At VHF and higher frequencies, small variations (turbulence) in the density of the atmosphere at a height of around 6 miles (10 km) can scatter some of the normally line-of-sight beam of radio frequency energy back toward the ground, allowing over-the-horizon communication between stations as far as 500 miles (800 km) apart. The military developed the White Alice Communications System covering all of Alaska, using this tropospheric scattering principle.

Tropospheric ducting

Sudden changes in the atmosphere's vertical moisture content and temperature profiles can on random occasions make microwave and UHF & VHF signals propagate hundreds of kilometers up to about 2,000 kilometers (1,300 mi)—and for ducting mode even farther—beyond the normal radio-horizon. The inversion layer is mostly observed over high pressure regions, but there are several tropospheric weather conditions which create these randomly occurring propagation modes. Inversion layer's altitude for non-ducting is typically found between 100 meters (300 ft) to about 1 kilometer (3,000 ft) and for ducting about 500 meters to 3 kilometers (1,600 to 10,000 ft), and the duration of the events are typically from several hours up to several days. Higher frequencies experience the most dramatic increase of signal strengths, while on low-VHF and HF the effect is negligible. Propagation path attenuation may be below free-space loss. Some of the lesser inversion types related to warm ground and cooler air moisture content occur regularly at certain times of the year and time of day. A typical example could be the late summer, early morning tropospheric enhancements that bring in signals from distances up to few hundred kilometers for a couple of hours, until undone by the Sun's warming effect.

Tropospheric delay

This is a source of error in radio ranging techniques, such as the Global Positioning System (GPS).[10] See also the page of GPS meteorology.

Rain scattering

Rain scattering is purely a microwave propagation mode and is best observed around 10 GHz, but extends down to a few gigahertz—the limit being the size of the scattering particle size vs. wavelength. This mode scatters signals mostly forwards and backwards when using horizontal polarization and side-scattering with vertical polarization. Forward-scattering typically yields propagation ranges of 800 km. Scattering from snowflakes and ice pellets also occurs, but scattering from ice without watery surface is less effective. The most common application for this phenomenon is microwave rain radar, but rain scatter propagation can be a nuisance causing unwanted signals to intermittently propagate where they are not anticipated or desired. Similar reflections may also occur from insects though at lower altitudes and shorter range. Rain also causes attenuation of point-to-point and satellite microwave links. Attenuation values up to 30 dB have been observed on 30 GHz during heavy tropical rain.

Airplane scattering

Airplane scattering (or most often reflection) is observed on VHF through microwaves and, besides back-scattering, yields momentary propagation up to 500 km even in mountainous terrain. The most common back-scatter applications are air-traffic radar, bistatic forward-scatter guided-missile and airplane-detecting trip-wire radar, and the US space radar.

Lightning scattering

Lightning scattering has sometimes been observed on VHF and UHF over distances of about 500 km. The hot lightning channel scatters radio-waves for a fraction of a second. The RF noise burst from the lightning makes the initial part of the open channel unusable and the ionization disappears quickly because of recombination at low altitude and high atmospheric pressure. Although the hot lightning channel is briefly observable with microwave radar, no practical use for this mode has been found in communications.

Other effects

Diffraction

Knife-Edge diffraction is the propagation mode where radio waves are bent around sharp edges. For example, this mode is used to send radio signals over a mountain range when a line-of-sight path is not available. However, the angle cannot be too sharp or the signal will not diffract. The diffraction mode requires increased signal strength, so higher power or better antennas will be needed than for an equivalent line-of-sight path.

Diffraction depends on the relationship between the wavelength and the size of the obstacle. In other words, the size of the obstacle in wavelengths. Lower frequencies diffract around large smooth obstacles such as hills more easily. For example, in many cases where VHF (or higher frequency) communication is not possible due to shadowing by a hill, it is still possible to communicate using the upper part of the HF band where the surface wave is of little use.

Diffraction phenomena by small obstacles are also important at high frequencies. Signals for urban cellular telephony tend to be dominated by ground-plane effects as they travel over the rooftops of the urban environment. They then diffract over roof edges into the street, where multipath propagation, absorption and diffraction phenomena dominate.

Absorption

Low-frequency radio waves travel easily through brick and stone and VLF even penetrates sea-water. As the frequency rises, absorption effects become more important. At microwave or higher frequencies, absorption by molecular resonances in the atmosphere (mostly from water, H_2O and oxygen, O_2) is a major factor in radio propagation. For example, in the 58–60 GHz band, there is a major absorption peak which makes this band useless for long-distance use. This phenomenon was first discovered during radar research in World War II. Above about 400 GHz, the Earth's atmosphere blocks most of the spectrum while still passing some - up to UV light, which is blocked by ozone - but visible light and some of the near-infrared is transmitted. Heavy rain and falling snow also affect microwave absorption.

Measuring HF propagation

HF propagation conditions can be simulated using radio propagation models, such as the Voice of America Coverage Analysis Program, and realtime measurements can be done using chirp transmitters. For radio amateurs the WSPR mode provides maps with real time propagation conditions between a network of transmitters and receivers.[11] Even without special beacons the realtime propagation conditions can be measured: a worldwide network of receivers decodes morse code signals on amateur radio frequencies in realtime and provides sophisticated search functions and propagation maps for every station received.[12]

See also

- Diversity scheme
- Earth bulge
- Earth-ionosphere waveguide
- Electromagnetic radiation
- Fading
- Fresnel zone
- Free space
- Inversion (meteorology)
- Kennelly–Heaviside layer
- Near and far field
- Radio atmospherics
- Radio frequency
- Radio horizon
- Radio propagation model
- Rayleigh fading
- Ray tracing (physics)
- Schumann resonance
- Skip (radio)
- Skip zone
- Skywave
- Tropospheric propagation
- TV and FM DX
- Upfade
- VOACAP - Free professional HF propagation prediction software

References

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2. ^ Demetrius T Paris and F. Kenneth Hurd, *Basic Electromagnetic Theory*, McGraw Hill, New York 1969 ISBN 0-07-048470-8, Chapter 8
3. ^ Radiowave propagation, edited by M.Hall and L.Barclay, page 2, published by Peter Peregrinus Ltd., (1989), ISBN 0-86341-156-8
4. ^ Radiowave propagation, edited by M.Hall and L.Barclay, published by Peter Peregrinus Ltd., page 3, (1989), ISBN 0-86341-156-8
5. ^ Westman *Reference data* page 26-19
6. ^ Clinton B. DeSoto (1936). *200 meters & Down - The Story of Amateur Radio*. W. Hartford, CT: The American Radio Relay League. pp. 132–146. ISBN 0-87259-001-1.
7. ^ G.W. Hull, "Nonreciprocal characteristics of a 1500km HF Ionospheric Path," *Proceedings of the IEEE*, 55, March 1967, pp. 426-427; "Origin of non-reciprocity on high-frequency ionospheric paths," *Nature*, pp. 483-484, and cited references.
8. ^ Davies, Kenneth (1990). *Ionospheric Radio*. IEE Electromagnetic Waves Series #31. London, UK: Peter Peregrinus Ltd/The Institution of Electrical Engineers. pp. 184–186. ISBN 0-86341-186-X.
9. ^ George Jacobs and Theodore J. Cohen, *Shortwave Propagation Handbook*. Hicksville, New York: CQ Publishing (1982), pp. 130-135. ISBN 978-0-943016-00-9

10. ^ Frank Kleijer (2004), Troposphere Modeling and Filtering for Precise GPS Leveling (http://www.ncg.knaw.nl/Publicaties/Geodesy/pdf/56Kleijer.pdf). Ph. D. thesis, Department of Mathematical Geodesy and Positioning, Delft University of Technology
11. ^ WSPR Propagation Conditions Map: http://wsprnet.org/drupal/wsprnet/map
12. ^ Network of CW Signal Decoders for Realtime Analysis: http://www.reversebeacon.net/

Further reading

- Lucien Boithais: *Radio Wave Propagation*. McGraw-Hill Book Company, New York. 1987. ISBN 0-07-006433-4
- Karl Rawer:*Wave Propagatiom im the Ionosphere*.Kluwer Acad.Publ.,Dordrecht 1993. ISBN 0-7923-0775-5
- H. Ward Silver and Mark J. Wilson, (eds), "Propagation of Radio Signals" (Ch. 19, by Emil Pocock), in *The ARRL Handbook for Radio Communications (88th edition, 2010), ARRL, Newington CT USA ISBN 0-87259-095-X*

External links

Wikimedia Commons has media related to ***Radio propagation***.

- Solar widget (http://rigreference.com/solar) Propagation widget based on NOAA data. Also available as WordPress plugin.
- ARRL Propagation Page (http://www.arrl.org/tis/info/propagation.html) The American Radio Relay League page on radio propagation.
- HF Radio and Ionospheric Prediction Service - Australia (http://www.ips.gov.au/HF_Systems/)
- NASA Space Weather Action Center (http://sunearthday.nasa.gov/swac/data.php)
- HF Propagation Tutorial by the late NM7M (http://www.astrosurf.com/luxorion/qsl-hf-tutorial-nm7m.htm)
- Space Weather and Radio Propagation Resource Center (http://sunspotwatch.com) Live data and images of space weather and radio propagation.
- Solar Terrestrial Dispatch (http://www.spacew.com/)
- Online Propagation Tools, HF Solar Data, and HF Propagation Tutorials (http://www.hamqsl.com/solar.html)
- DXing.info - Propagation links (http://www.dxing.info/propagation)
- HF Radio Propagation Software for Firefox - Propfire (http://www.n0hr.com/Propfire.htm) Firefox plug-in for monitoring propagation, website utility to display HF propagation status, and article on understanding HF radio propagation forecasting
- The Basics of Radio Wave Propagation (http://ecjones.org/propag.html) A resource by Edwin C. Jones (AE4TM), MD, PhD, Department of Physics and Astronomy, University of Tennessee.
- Dynamic Radio Propagation Data (http://dx.qsl.net/propagation/propagation.html) Constantly updated radio propagation data pulled from various sources.
- Solar Cycle 24 prediction and MF/HF/6M radiowave propagation forecast webpage (www.solarcycle24.org) (http://www.solarcycle24.org/)
- 160 Meter (Medium Frequency) Radiowave Propagation Theory Notes webpage

(www.wcflunatall.com/nz4o5.htm) (http://www.wcflunatall.com/nz4o5.htm/)

- Unusual HF Propagation Phenomena. 13 Apr 2009 (http://www.qslnet.de/member/la3za/prop/) Includes useful recordings each type. Retrieved 9 Oct 2009.
- Overview of radio propagation modes (http://www.radio-electronics.com/info/propagation/radio-propagation/radio-propagation-overview-tutorial.php)
- Propagation: Es & Thunderstorms (http://lists.contesting.com/archives//html/Propagation/2005-04/msg00075.html) by Thomas F. Giella, NZ4O, ex KN4LF.

The following external references provide practical examples of radio propagation concepts as demonstrated using software built on the VOACAP model.

- Online MOF/LOF HF Propagation Prediction Tool (http://www.hamqsl.com/solar1.html#moflof)
- High Frequency radio propagation de-mystified. (http://hfradio.org/ace-hf/ace-hf-demystified.html)
- Is High Frequency radio propagation reciprocal? (http://hfradio.org/ace-hf/ace-hf-reciprocal.html)
- How does noise affect radio signals? (http://hfradio.org/ace-hf/ace-hf-noise.html)

The following external link is designed for use by cell phones and mobile devices that can display content using Wireless Markup Language and the Wireless Application Protocol:

- WAP/WML Space Weather and Radio Propagation Resources (http://wap.hfradio.org/) Space weather and radio propagation resources.

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