PROPAGATION ON THE "MAGIC BAND"
By Robert Magnani K6QXY

6 meters is a very unique amateur band. Every mode of propagation known to exist can be found here. In fact, the 6 meter amateur band was actually an FCC compromise that recognized the importance of this block of frequencies. Originally the Commission was going to give amateurs a band between 44 and 48 mhz. Intense lobbying by the ARRL convinced the FCC there were enough "unique propagation attractions" to assign the 6 meter band to 50-54 mhz. There are three major forms of propagation that can cause real excitement on the "Magic Band".

F-Layer Propagation
Approximately every 11 years the sun explodes into violent solar storms. These solar storms produce sufficient amounts of radiation to excite the F-layer producing a very radio reflective surface. A smoothed sun spot number of at least 120 is needed for the M.U.F. (maximum useable frequency) to reach 50 mhz. When this occurs, 50 mhz. signals can be propagated to distances exceeding 10,000 miles!!!!

The height of the ionized F2 layer reflections produce single hop distances approaching 2,500 miles. With the sun rotating on its axis every 27-28 days, a sun spot or complex group of spots, will again face the earth and a particular series of events will often repeat itself every 27-28 days.

Transequitorial Propagations
One of the most exciting propagation modes is transequitorial propagation or "TEP". TEP is really the scattering from ionospheric irregularities at very high altitudes. Actually TEP was discovered by amateurs during the late 1950's. They called the new mode "Transequitorial Field Aligned Irregularities".

TEP forms across the "Geomagnetic Equator", with stations ideally situated on a north south axis at equal distances either side of the "Geomagnetic Equator". Occurring near the two solar equinoxes in March and September, TEP occurs in the late afternoon and early evening. There is a strong positive correlation with the solar cycle peak. M.U.F.'s of TEP signals can often exceed 400 mhz. There is a strong correlation between the formation of TEP and auroral events. TEP signals often exhibit the same "garbled" characteristics as that of auroral scattered signals.

Sporadic E
One of the most misunderstood VHF propagations modes is "Sporadic E". Sporadic E normally displays a major peak during the summer months of May through August, and then again with a minor peak in the winter months of November and December.

Sporadic E appears to be reflections from dense patches of ionization that form at E-layer heights. The height of the E-Layer reflections produce single hop distances on the order of 1,200 miles. One, two, three and even four hop sporadic E has occurred with distances exceeding 5,000 miles. Whether they are actually hops that touch the earth or "Chordial Hops" that just graze the earth or even "cloud to cloud reflections" is not clear. The actual cause of sporadic E is unknown. Theories include high altitude wind sheer and the generation of strong electron fields associated with high altitude thunder storms.

Research now indicates that certain “multi-hop Sporadic E” paths, especially those that cross the “Auroral E Zone” and the “Equitorial E Zone” exhibit strong “diurnal” characteristics. These paths show a remarkable consistency in time of day, month and year repeatability. There does not seem to be any correlation with the 11 year solar cycle, but data seems to suggest a 5-7 year cycle with a 5-7 day underlying cycle.

Other forms of propagation on the “Magic Band” include “**meteor scatter**”, “**aurora**” and “**Auroral E’s**” plus the various scatter modes. All of these in combinations with the above mentioned major modes contribute to exciting times on 6 meters.

*** WA3WSJ Notes**

Here are the various forms of 6M propagation I have found:

Aurora

One of the most interesting propagation phenomena is Aurora propagation. To make use of this phenomenon, radio amateurs actually bounce their signals off of the Aurora Borealis, also known as the “Northern Lights.” All of these choices are correct when talking about effects Aurora activity has on radio communications (E3C01):

- SSB signals are raspy
- Signals propagating through the Aurora are fluttery
- CW signals appear to be modulated by white noise

The cause of Aurora activity is the interaction of charged particles from the Sun with the Earth’s magnetic field and the ionosphere. (E3C02) Aurora activity occurs in the E-region of the ionosphere. (E3C03) CW is the emission mode that is best for Aurora propagation. (E3C04) From the contiguous 48 states, an antenna should be pointed North to take maximum advantage of aurora propagation. (E3C11)

Aurora E

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

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. .

Backscatter
Usually two nearby stations cannot hear each another due to the skip or silent zone that surrounds them. Therefore on HF bands you generally cannot hear stations in a range of about 200 km around your QTH on the 10m band and you can get better results on the lower bands where the skip distance is shorter or does not exist. But under special ionospheric conditions these two same nearby stations might be able to communicate thanks to the back or sidescatter.

If you work near the MUF limit for a given path and time, after the first skip via the E or F-layer, your signal is reflected to the ground. A part of these emissions is reflected back in an area shared by both emitters. Signals are very modulated and highly recognizable, sounding like expressed in a huge cathedral or similar to a hollow sound with no evidence of fading.

This effect contributes to DX activities where contacts over 5000 km are possible especially during the periods of low solar activities when the normal ionospheric propagation is deeply affected.

F2 propagation (F2-skip)
The F2 layer is found about 200 miles (320 km) above the Earth's surface and can reflect radio waves back toward the Earth. When the layer is particularly strong during periods of high sunspot activity, FM and TV reception can take place over 2000 miles (3000 km) or more, as the signal effectively "bounces" off the high atmospheric layer.

The E layer of the ionosphere is not the only layer that can reflect VHF television signals. Less frequently, the higher F2 layer can also propagate VHF signals several thousand miles beyond their intended area of reception.

Solar activity has a cycle of approximately 11 years. During this period, sunspot activity rises to a peak and gradually falls again to a low level. When sunspot activity increases, the reflecting capabilities of the F1 layer surrounding earth enable high frequency short-wave communications. The highest-reflecting layer, the F2 layer, which is approximately 200 miles (320 km) above earth, receives ultraviolet radiation from the sun, causing ionisation of the gases within this layer. During the daytime when sunspot activity is at a maximum, the F2 layer can become intensely ionized due to radiation from the sun.

When solar activity is sufficiently high, the MUF (Maximum Usable Frequency) rises, hence the ionisation density is sufficient to reflect signals well into the 30 – 50 MHz VHF spectrum. Since the MUF progressively increases, F2 reception on lower frequencies can indicate potential low band 45-55 MHz VHF TV as well as VHF amateur radio paths. A rising MUF will initially affect the 27 MHz CB band, and the amateur 28 MHz 10 meters band before reaching 45-55 MHz TV and the 6 Meter amateur band. The F2 MUF generally increases at a slower rate compared to the Es MUF.

Since the height of the F2 layer is some 200 miles (320 km), it follows that single-hop F2 signals will be received at thousands rather than hundreds of miles. A single-hop F2 signal will usually be around 2,000 miles (3,200 km) minimum. A maximum F2 single-hop can reach up to approximately 3,000 miles (4,800 km). Multi-hop F2 propagation has enabled low-band VHF reception to over 11,000 miles (17,700 km).

Since F2 reception is directly related to radiation from the Sun on both a daily basis and in relation to the sunspot cycle, it follows that for optimum reception the centre of the signal path will be roughly at midday.

The F2 layer tends to predominantly propagate signals below 40 MHz, which includes the 27 MHz CB band, and 28 MHz 10-metre Amateur radio band. Less frequently, television and amateur signals in the 45 – 55 MHz VHF band are also propagated over considerable distances. In North America, F2 is most likely to only affect VHF TV channel 2.

Television pictures propagated via F2 tend to suffer from characteristic ghosting and smearing. Picture degradation and signal strength attenuation increases with each subsequent F2 hop.

Multihop ES

There is also another way to exceed the maximum distance allowed by the F2-layer : the *multihop*. When conditions are in favor of DX, bands open down to QRP stations, instead of working a near station in doing only one jump or a single "hop" via the F2-layer, we can reach far DX stations in doing several hops and break the skip distance wall of 1500 km on the higher frequencies. In using a very low incidence angle, if the first signal reflects well to the upper layers of the ionosphere and then impacts the ground far from your home, hop after hop this multihop propagation allows communications with stations located on the other side of the Earth. It is of course subject to fading and attenuation each time that the radio wave is reflected or partially refracted, but signals can also be stable with few attenuation if the ionospheric absorption is very weak. The famous "DX bands" between 20 and 15m are the best for this type of traffic. In these bands, even equipped with a wire antenna or a vertical and 100W PEP out, you can work stations located over 10000 km away, and, from Europe, work stations in the middle of the Pacific ocean if conditions are met.

At last, as we just speak about the ionospheric F-layer and hop, it is great time to introduce the concept of propagation mode, to not confuse with the modulation mode like CW or SSB. A propagation mode is the path that radio wave takes when travelling between a transmitter and a receiver. These paths are many and various, via the E-layer, Es-layer, F-layer, even mixed, etc. Then each mode is associated to a certain number of hop to establish the contact : one hop via the F1-layer is listed as 1F, two hops via the F2-layer is listed 2F2, etc. Remember also the higher the order of the mode (or the more hops it has, 3F, 4F,...), the lower its signal strength. Indeed each reflection of a radio wave at either the ground or ionosphere results in loss of energy. One considers that a typical ground reflection losses for DX hops (long distance and low elevation angles) are 3 dB for a poorly conducting ground and 0.5 dB for reflection from the sea, without to mention that the E-layer is a much poorer reflector than the F-layer for example. When we know that a loss of 3 dB represents a decreasing of half (50%) of the signal strength, you quickly understand all the interest of working near the sea and using an antenna offering a very low takeoff angle... We will come back on these concepts on other pages dealing with antenna properties and performances

Sporadic E

Sporadic E or Es is an unusual form of radio propagation using characteristics of the Earth's ionosphere. Whereas most forms of skywave propagation use the normal and cyclic ionization properties of the ionosphere's F region to refract (or "bend") radio signals back toward the Earth's surface, sporadic E propagation bounces signals off smaller "clouds" of unusually ionized atmospheric gas in the lower E region (located at altitudes of approx. 90 to 160 km). This occasionally allows for long-distance communication at VHF frequencies not usually well-suited to such communication.

Communication distances of 800–2200 km can occur using a single Es cloud. This variability in distance depends on a number of factors, including cloud height and density. MUF also varies widely, but most commonly falls in the 27–110 MHz range, which includes the FM broadcast band (87.5–108 MHz), Band I VHF television (American channels 2-6, Russian channels 1-3, and European channels 2-4, the latter no longer widely used in Western Europe), CB radio (27 MHz) and the amateur radio 10- and 6-meter bands. Strong events have allowed propagation at frequencies as high as 250 MHz.[

As its name suggests, sporadic E is an abnormal event, not the usual condition, but can happen at almost any time; it does, however, display seasonal patterns. Sporadic E activity peaks predictably in the summertime in both hemispheres. In North America, the peak is most noticeable in mid-to-late June, trailing off through July and into August. A much smaller peak is seen around the winter solstice. Activity usually begins in mid-December in the southern hemisphere, with the days immediately after Christmas being the most active period.

Transequatorial propagation (TEP)

Discovered in 1947, transequatorial spread-F (TE) propagation makes it possible for reception of television and radio stations between 3,000–5,000 miles (4,800–8,000 km) across the equator on frequencies as high as 432 MHz. Reception of lower frequencies in the 30 – 70 MHz range are most common. If sunspot activity is sufficiently high, signals up to 108 MHz are also possible. Reception of TEP signals above 220 MHz is extremely rare. Transmitting and receiving stations should be nearly equidistant from the geomagnetic equator.

The first large-scale VHF TEP communications occurred around 1957 – 58 during the peak of solar cycle 19. Around 1970, the peak of cycle 20, many TEP contacts were made between Australian and Japanese radio amateurs. With the rise of cycle 21 starting around 1977, amateur contacts were made between Greece/Italy and Southern Africa (both South Africa and Rhodesia/Zimbabwe), and between Central and South America by TEP.

"Afternoon" and "evening" are two distinctly different types of trans-equatorial propagation.

Tropospheric Propagation
Tropospheric propagation refers to the way radio signals travel through the lowest layer of the Earth's atmosphere, the troposphere, at altitudes up to about to 17 km (11 miles). Weather conditions in the lower atmosphere can produce radio propagation over greater ranges than normal. If a temperature inversion occurs, with upper air warmer than lower air, VHF and UHF radio waves can be refracted over the Earth's surface instead of following a straight-line path into space or into the ground. Such "tropospheric ducting" can carry signals for 800 km (500 miles) or more, far beyond usual range.

EME
Earth – Moon – Earth (EME) propagation (Moonbounce)
The Arecibo Radio Telescope spherical reflector antenna has been used for detecting terrestrial television signals reflected off the lunar surface.

Since 1953, radio amateurs have been experimenting with lunar communications by reflecting VHF and UHF signals off the moon. Moonbounce allows communication on earth between any two points that can observe the moon at a common time.[

Since the moon's mean distance from earth is 239,000 miles (385,000 km), path losses are very high. It follows that a typical 240 dB total path loss places great demand on high-gain receiving antennas, high-power transmissions, and sensitive receiving systems. Even when all these factors are observed, the resulting signal level is often just above the noise.

Because of the low signal-to-noise ratio, as with amateur-radio practice, EME signals can generally only be detected using narrow-band receiving systems. This means that the only aspect of the TV signal that could be detected is the field scan modulation (AM vision carrier). FM broadcast signals also feature wide frequency modulation, hence EME reception is generally not possible. There are no published records of VHF/UHF EME amateur radio contacts using FM.

Meteor Scatter
also referred to as meteor scatter communications,[is a radio propagation mode that exploits the ionized trails of meteors during atmospheric entry to establish brief communications paths between radio stations up to 2,250 kilometres (1,400 mi) apart.

As the earth moves along its orbital path, billions of particles known as meteors enter the earth's atmosphere every day; a small fraction of which have properties useful for point to point communication.[2] When these meteors begin to burn up, they create a trail of ionized particles in the E layer of the atmosphere that can persist for up to several seconds.

The ionization trails can be very dense and thus used to reflect radio waves. The frequencies that can be reflected by any particular ion trail are determined by the intensity of the ionization created by the meteor, often a function of the initial size of the particle, and are generally between 30 MHz and 50 MHz.

Have you ever try to work in HF with "shooting stars" ?... If you erect a yagi above the horizontal plane in order to point in the direction near the radiant of meteors showers - Perseids, Leonids, etc - each time a meteor will strike the upper atmosphere above or at a few hundred km from your location, while burning in penetrating the denser layers of the atmosphere you can use its ionization trace as a reflector to reach other hams working a similar way.

List of meteors showers

The Leonid 1997 shower seen from space. Each white dot or line is a meteor striking the upper atmosphere. Doc SETI Institute colorised by the author.

To work a MS station, both hams have to be placed symmetrically with the meteor trajectory and the density of the ionosphere must reach a high value in order that the ionized trail is able to reflect shortwaves in place of absorbing them.

Most of these radio waves are scattered at the E-level and can be used on frequencies from 6 m to 60 cm but also in the HF band of 10 m.

As meteors enter the atmosphere at very high speeds, most between 60 and 72 km/s, the scatter of radio waves last only a few seconds. In very exceptional circumstances the trace last a few minuts while the smoke has already persisted over one hour !

You will record the best the meteors during the first hours of the morning until dawn because the eastern side of the Earth captures much more meteors during its rotation than the opposite side where meteors have to catch up with Earth on its orbit. Therefore in the morning the meteors are more numerous, their are more bolids and their trail is also brighter than before midnight.

The ionized clouds moves at a speed of about 72 km/h or 0.02 km/s, thousand times slower than a fast meteor !

Echo of a strong Geminid (MP3 of 534 KB) recorded on Dec 15, 2003 at 1140 UTC by the author using a Navspasur radar tuned on 217 MHz. Recording made via Internet.

To work a station in a few seconds delay requests special equipments, often directive aerials, and preprogrammed procedures. This activity is mainly practiced in APRS and VHF packet radio where signals are categorized either as "ping" or "burst" depending their last and strength. Meteors Scatter allows of course SSB communications. Click on this file to listen an MS communication via a Leonid worked by F6CRP in 2000 (.MP3 file of 63 KB). Other recordings are available on this page.

For more information about MS and other EME activity I suggest you to subscribe to the european magazine DUBUS or take a look at the following websites : Meteor Scatter.Net and Jordanian Astronomical Society. Refer also to the Meteor-Scatter page for more detail about this exciting activity.

If you are only interested in counting the number of meteors falling from the sky during a shower, Pierre Terrier intends to help you in building a monitoring system based on FM signals called the "Radiometeor". In addition he also provides an analysis software called HROFFT2RMOB.

The distance over which communications can be established is determined by the altitude at which the ionization is created, the location over the surface of the Earth where the meteor is falling, the angle of entry into the atmosphere, and the relative locations of the stations attempting to establish communications. Because these ionization trails only exist for fractions of a second to as long as a few seconds in duration, they create only brief windows of opportunity for communications.[

Most meteor scatter communications is conducted between radio stations that are engaged in a precise schedule of transmission and reception periods. Because the presence of a meteor trail at a suitable location between two stations cannot be predicted, stations attempting meteor scatter communications must transmit the same information repeatedly until an acknowledgement of reception from the other station is received. Established protocols are employed to regulate the progress of information flow between stations. While a single meteor may create an ion trail that supports several steps of the communications protocol, often a complete exchange of information requires several meteors and a long period of time to complete.

Any form of communications mode can be used for meteor scatter communications. Single sideband audio transmission has been popular among amateur radio operators in North America attempting to establish contact with other stations during meteor showers without planning a schedule in advance with the other station. The use of Morse code has been more popular in Europe, where amateur radio operators used modified tape recorders, and later computer programs, to send messages at transmission speeds as high as 800 words per minute. Stations receiving these bursts of information record the signal and play it back at a slower speed to copy the content of the transmission. Since 2000, several digital modes implemented by computer programs have replaced voice and Morse code communications in popularity. The most popular program for amateur radio operations is WSJT, which was written explicitly for meteor scatter communications.

Ionoscatter

In this mode both hams have to bear their antenna to a shared area in the E-layer of the ionosphere near 90 km aloft, where their respective signals are scattered forward. This VHF traffic requires efficient antennas and is open permanently, at all hours of the day and night. According hams specialized in this traffic, no elevation is request for antennas if the distant station is located over 2000 km away. Howerver, for shorter distance, around 1200 km, an elevation of about 5° is required.

This type of traffic is the most efficient between 50 and about 70 MHz and takes also advantage of the ionization trail left by meteors that contribute to scatter radio signals. But contrary to the Meteor Scatter, here the signals received are continuous and weak. Thefeore most hams work with linear amplifiers over 500 W and beams offering a gain over 10 dBd.

Aircraft Scatter
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.

The scattering of radio signals by aircraft is an example of Bistatic Radar theory. This may sound like a difficult subject to understand, but the underlying principles are simple enough. "Bistatic" just means that the receiver and the transmitter are in different places let me walk you through the basic ideas.

- Imagine a transmitter of known power with an antenna of known gain – including any ground gain.

- Now imagine an aircraft some large distance away (say 300km), which presents some area which intercepts part of the radio signal.

- Calculate how much of the transmitted power falls on this "aircraft area". This is quite easy if you know the area, or can make some estimate of it.

- Assume that all (or most) of this power is reradiated by the aircraft area, acting much like a large antenna or dish with some radiation pattern.

- Having regard to the pattern of the scattered radiation, calculate how much power falls on the capture area of the receiving antenna (directly related to its gain and the wavelength).

http://vhfdx.radiocorner.net/docs/AircraftScatter.pdf

FAI: .Field Aligned Irregularities
The F.A.I is due to irregularities E-Layer ionization aligned to the earth magnetic field. The irregularities E-Layer ionization grows a zone of scatter where the Vhf emission are reflected. The propagation was short lived and disappeared when the heaters were turned off.

Several condictions are requiered to establish a F.A.I. radio link:
Suitable ionospheric condictions must be available. Furthermore, a suitable scatter geometry must be set up by the locations of the transmitter, receiver and scatterer. In particular both the transmitter's and receiver's antenna must be directed at a common scatter volume. These requirements were furfilled for the observations in concern, otherwise these QSO's couldnot have been made.

A radio signal illuminating FAI will be scattered back to ground in a cone shaped pattern with the apex at the irregularity and the axis aligned to magnetic field line. The intersection with the earth of the scattering cone, having an angle a2 to the magnetic field line, gives the contour of the maximum reception which is also labelled a2. Contacts may take place between stations located on supplementary countors(their sum is equal 180 deg.)

Signal Characteristic -
F.A.I is different from Sporadic E or Tropo for the following main charatteristics :
Signal offset from the great circle bearing.
Rapid flutter, it is similar to auroral propagation in sound, but not as disruptive. Frequency components of 30 to 100 Hz are tipical. Ssb is quite intellegible when signals are somewhat above the noise.

With qsos in CW is preferable low speed .
Heigth of Scatter
The heigth of E-Layer is about 100-140 Km. Therefore the proper elevation of the antenna is decreasing with increasing of the distance of the station from the scatter point.
IW1AZJ Silvio in Turin at 150 Km. distance of the scatter use 35 ° of antenna elevation.
IC8CQF Lino in Island of Capri at 800 Km distance of the scatter use 6° of antenna elevation. So the station near the scatter point that do not have an antenna system elevation could use one fix antenna with a just elevation.

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