MUF, LUF, and FOT - The Basics of the Maximum Usable Frequency

aus http//hfradio.org/muf_basics.html **DJ1SP 10.05.2004**

There are two definitions for the abbreviation, "MUF." The International Telecommunications Union ITU-R (Recommendation P.373-7 10/1995, in force) recommends two definitions for MUF:

1. **Operational MUF** (or just MUF) is the highest frequency that would permit acceptable operation of a radio service between given terminals at a given time under specific working conditions (antennas, power, emission type, required S/N ratio, and so forth), and,

2. **Basic MUF**, being the highest frequency by which a radio wave can propagate between given terminals by ionospheric propagation alone, independent of power.

The difference in frequency between operational MUF and basic MUF is in practice from ten to thirty-five percent. In most prediction software and in amateur radio and shortwave listening references the MUF refers to the first definition. On each day of the month at a given hour, there is a maximum observed frequency (MOF) for a mode. The median of this distribution is called the MUF. In other words, the MUF is the frequency for which ionospheric support is predicted on 50% of the days of the month, i.e. 15 days out of 30 days. So on a given day communications may or may not succeed on the frequency marked as the MUF.

To ensure a good communication link between two locations, the operating frequency is typically chosen below the predicted MUF. A commonly used formula for finding the optimal operating frequency for a given path is to calculate between **80 to 90% of the MUF**. Depending on what model you use for determining MUF and OWF, this percentage of usable days may be 50% or 90%. VOACAP uses 50%, for example. Synonyms for the optimal operating frequency are **FOT (frequency of optimum traffic), OTF (optimum traffic frequency or optimum transmission frequency), and OWF (optimum working frequency).**

So, as an example, if you find that the MUF is 23 MHz on a day with a Smoothed Sunspot Number of 130, over a path between you and some far off point, you would find the OWF as between 18.4 MHz and 20.7 MHz. You might be able to work 15 meters to that distant point. Most likely, you would find better conditions on 17 meters.

There are more factors involved in finding the "right" frequency to use between two points. These include absorption by lower regions (like the D layer), the "take off angle" of the radio signal from the originating antenna, and so forth.

The ionosphere is made up of several regions. The ionosphere is that part of the atmosphere, extending from about 70 to 500 kilometers, in which ions and free electrons exist in sufficient quantities to reflect and/or refract electromagnetic waves. These regions are the F2 region (250 to 400 km above the Earth), the F1 region (160 to 250 km), the E region (95 to 130 km), and the D region (50 to 95 km), under which is the Troposphere and so forth.

When a radio signal (an electromagnetic wave) propagates into the ionosphere, it might be absorbed, attenuated, refracted, or it might shoot right through and out into space. If a signal makes it through the lower regions, a redirection will occur for those signals whose frequencies are at or below a "critical" frequency (that being the frequency just below those that punch through the F regions and out into space). The redirection is a bending by a complex processing involving reflection and refraction. Depending on the angle of the radio wave (or, "angle of incidence") as it enters the region where it is redirected, the signal will be "reflected" back to the Earth at some variably distant point. Think of a flashlight beam that you shine at a mirror. When you shine on the mirror straight on, you have the beam of light coming almost straight back at you, but if you angle the light beam, the reflected light will move further away from you. The amount of radio wave bending depends on the extent of penetration (which is a function of frequency), the angle of incidence, polarization of the wave, and ionospheric conditions, such as the ionization density.

The **Lowest Usable Frequency (LUF)** is that frequency in the HF band at which the received field intensity is sufficient to provide the required signal-to-noise ratio for a specified time period, e.g., 0100 to 0200 UTC, on 90% of the undisturbed days of the month. The amount of energy absorbed by the lower regions (D region, primarily) directly impacts the LUF. If a signal at 5 MHz is totally absorbed by the D region, but a signal at 6 MHz makes it through without a lot of loss, and the E or F layer refracts the 6 MHz signal, the LUF will be near that 6 MHz part of the spectrum. The MUF might be 12 MHz. The OWF (optimum working frequency) will be somewhere between 6 and 12 MHz, probably around 10 MHz.

Frequency of Optimum Transmission (FOT): In the transmission of radio waves via ionospheric reflection, the FOT is the highest effective frequency (or best working frequency) for a given path that is predicted to be usable for a specified time for a percentage of the days of the month.