Maximum Usable Frequency

As we discussed earlier, the higher the frequency of a radio wave, the lower the rate of refraction by an ionized layer. Therefore, for a given angle of incidence and time of day, there is a maximum frequency that can be used for communications between two given locations. This frequency is known as the MAXIMUM USABLE FREQUENCY (muf).

Waves at frequencies above the muf are normally refracted so slowly that they return to Earth beyond the desired location, or pass on through the ionosphere and are lost. You should understand, however, that use of an established muf certainly does not guarantee successful communications between a transmitting site and a receiving site. Variations in the ionosphere may occur at any time and consequently raise or lower the predetermined muf. This is particularly true for radio waves being refracted by the highly variable F2 layer. The muf is highest around noon when ultraviolet light waves from the sun are the most intense. It then drops rather sharply as recombination begins to take place.

$$\therefore \sin\phi_i = \sqrt{1 - \frac{81 N_{max}}{f^2_{muf}}}$$

Squaring both sides

$$\sin^2\phi_i = 1 - \frac{81 N_{max}}{f^2_{muf}}$$

$$\therefore \frac{81 N_{max}}{f^2_{muf}} = 1 - \sin^2\phi_i = \cos^2\phi_i$$

but $f_{cr} = \sqrt{81 N_{max}}$

$$\therefore \frac{f_{cr}^2}{f^2_{muf}} = \cos^2\phi_i$$

$$\therefore f_{muf} = \frac{f_{cr}}{\cos\phi_i} = \sec\phi_i \, f_{cr}$$

∴ The f_{muf} is always greater than f_{cr} of the layer by the factor $\sec\phi_i$. This is called Secant law.

Lowest Usable Frequency

As there is a maximum operating frequency that can be used for communications between two points, there is also a minimum operating frequency. This is known as the LOWEST USABLE FREQUENCY (luf). As the frequency of a radio wave is lowered, the rate of refraction increases. So a wave whose frequency is below the established luf is refracted back to Earth at a shorter distance than desired, as shown in figure

The transmission path that results from the rate of refraction is not the only factor that determines the luf. As a frequency is lowered, absorption of the radio wave increases. A wave whose frequency is too low is absorbed to such an extent that it is too weak for reception. Likewise, atmospheric noise is greater at lower frequencies; thus, a low-frequency radio wave may have an unacceptable signal-to-noise ratio. For a given angle of incidence and set of ionospheric conditions, the luf for successful communications between two locations depends on the refraction properties of the ionosphere, absorption considerations, and the amount of atmospheric noise present.

Optimum Working Frequency

Neither the muf nor the luf is a practical operating frequency. While radio waves at the luf can be refracted back to Earth at the desired location, the signal-to-noise ratio is still much lower than at the higher frequencies, and the probability of multipath propagation is much greater. Operating at or near the muf can result in frequent signal fading and dropouts when ionospheric variations alter the length of the transmission path. The most practical operating frequency is one that you can rely on with the least amount of problems. It should be high enough to avoid the problems of multipath, absorption, and noise encountered at the lower frequencies; but not so high as to result in the adverse effects of rapid changes in the ionosphere. A frequency that meets the above criteria has been established and is known as the OPTIMUM WORKING FREQUENCY. It is abbreviated "fot" from the initial letters of the French words for optimum working frequency, "frequence optimum de travail." The fot is roughly about 85 percent of the muf but the actual percentage varies and may be either considerably more or less than 85 percent.

Skip Distance/Skip Zone

The relationship between the sky wave skip distance, the skip zone, and the ground wave coverage. The SKIP DISTANCE is the distance from the transmitter to the point where the sky wave is first returned to Earth. The size of the skip distance depends on the frequency of the wave, the angle of incidence, and the degree of ionization present.

The SKIP ZONE is a zone of silence between the point where the ground wave becomes too weak for reception and the point where the sky wave is first returned to Earth. The size of the skip zone depends on the extent of the ground wave coverage and the skip distance. When the ground wave coverage is great enough or the skip distance is short enough that no zone of silence occurs, there is no skip zone. Occasionally, the first sky wave will return to Earth within the range of the ground wave. If the sky wave and ground wave are nearly of equal intensity, the sky wave alternately reinforces and cancels the ground wave, causing severe fading. This is caused by the phase difference between the two waves, a result of the longer path traveled by the sky wave.

$$D_{skip} = 2h \sqrt{[(f_{muf} / f_c)^2 - 1]}$$

MULTI -HOP PROPAGATIONS

The coverage of transmission distance between transmitter and receiver in more than one hop is called multi-hop propagation.
The longest single hop propagation is obtained when the transmitted ray is tangential at the earth surface.
The maximum practical distance covered by a single hop is 2000 km for E layer and 4000 km for F2 layer.
Multi-hop propagation paths occur when the semicircumference of the earth is just over 20,000 km.

VIRTUAL HIGHT

Defined as the height to which a short pulse of energy sent vertically upward.
It will always be greater than the actual height.
If it is known, it is easy to calculate the angle of incidence required for the wave to return at a desired point.
The measurement of virtual height is normally carried out by means of an instrument known as ionosonde.

$H = CT/2$, C – velocity of light, T – Round trip time.

METHOD OF VIRTUAL HIGHT MEASUREMENT

Transmit a signal that consists pulses of RF energy of short duration.
Receiver which is located close to the transmitter picks up both the direct and the reflected signals.
The spacing between these signals on the time axis of CRO gives a measurement of the height of the layer.
Useful in transmission path calculations.