Those New *QST* Propagation Charts

With LUF curves now shown in the monthly graphs, you can intelligently choose the bands and the times of day for the best probable propagation conditions to the DX areas of your choice.

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Beginning with this issue, the propagation-prediction graphs appearing in the How's DX? column convey some different information than has appeared in the past. You should find the new information very helpful when you're choosing the bands and the times to use during a contest, for going after that DX country you've been trying to snag, for making a schedule, or for just making a general contact with a particular distant area.

As anyone who frequently uses the HF bands knows, propagation conditions change with the time of day and often from one day to the next. Propagation also changes from month to month and with the so-called 11-year solar cycle. Soon we'll see the close of Solar Cycle 22, which began in September 1986; present indications are that it will bottom out and end late in 1995 or sometime in 1996. With the decline in solar activity, band openings on 10, 12 and 15 meters will become fewer and farther between. During the solar minimum, bands at the higher end of the HF spectrum may never come alive for weeks on end. In these coming times, information from *QST*'s How's DX? charts will help answer the recurring question, "Is the band dead, or is there just no one out there transmitting?"

Propagation Predictions

Short-term changes in propagation cannot be accurately predicted far in advance, and that's where listening to WWV or WWVH will bring you up to date on current conditions. How to use that information is discussed in more detail later in this article. Long-term changes—variances with month and with the level of solar activity—are taken into account by each of many computer programs that are available. IONCAP, one of the most sophisticated programs, is used at ARRL Headquarters to prepare the How's DX? charts.[1]

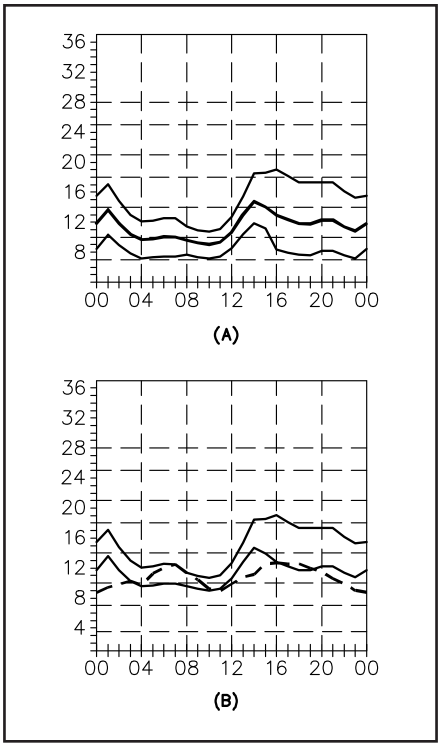

Figure 1—Curves showing propagation probabilities from Mid-USA to Central Asia during the period from mid-October to mid-November 1994. The vertical axis indicates frequency in MHz, and the horizontal axis, Coordinated Universal Time (UTC). The curves at **A** (HPF/median MUF/FOT) are those appearing in previous issues of *QST*, while those at **B** (HPF/median MUF/LUF) appear beginning with this issue. See text for details on these and other changes.

All IONCAP results are based on *probabilities*.

Propagation charts have appeared in *QST* since January 1977.[2] See Figure 1A, depicting the style of charts that were adopted in September 1977. This chart shows propagation estimations for the path from Mid-USA (Kansas City) to Central

Table 1
Path Terminal Points

General Location	*Actual Location**
West Coast	San Francisco, CA
Mid-USA	Kansas City, MO
East Coast	Washington, DC
South America	Asuncion, Paraguay
Central Asia	New Delhi, India
Southern Africa	Lusaka, Zambia
Western Europe	London, England
Eastern Europe	Kiev, Ukraine
Japan	Tokyo
Australia	Sydney
South Pacific	Pago Pago, Samoa
Alaska	Anchorage
Hawaii	Honolulu
Caribbean	San Juan, Puerto Rico

*Latitudes and longitudes used for the actual locations are those appearing in Table 4-3 of *The ARRL Operating Manual*, 4th edition.

Asia (New Delhi, India). The uppermost curve shows the highest possible frequency or HPF. Based on probabilities, the ionosphere will support these frequencies on 10% of the days of the propagation period, or about 3 days of the mid-October to mid-November prediction period. The middle curve shows the median maximum usable frequency or median MUF. The ionosphere will likely support these frequencies on 50% of the days, about 15 days of the split-month period. (A word of caution here: Don't be misled when the word median is dropped in referring to this curve, as is often done. The median or 50% MUF is not the same as the true MUF, which is the maximum frequency that will be propagated via the ionosphere between the two end-points of a given path at a given time.)

The lower curve in Figure 1A shows the frequency of optimum transmission or FOT. Propagation at these frequencies will probably be supported by the ionosphere for 90% of the days, about 27 days of the period. By implication, you should almost be guaranteed a QSO if you attempt con-

[1]Notes appear on page 30.

tacts at times and frequencies indicated by the FOT curve, right? This is the "optimum" frequency, so how can you go wrong? Let's follow up on this idea while referring to Figure 1A; it looks as if a great opportunity to work Central Asia from Mid-USA is on 40 meters between 0400 and 1000 UTC (10 PM to 4 AM CST). The FOT curve is relatively flat during this time period, and it hugs the broken line representing the 40-meter amateur band all the while.

Table 2
Parameters Used for IONCAP Calculations

Transmitter power: 1500 W

Antennas at each end of the path:

Data is read from an external binary antenna file created especially for preparing these *QST* propagation charts. The data is based on dipole and Yagi antenna elevation patterns, modified for a constant gain at elevation angles above the peak response of the lowest lobe in the patterns. (Of course the peak angle changes with frequency and with antenna height.) The constant-gain characteristic at the higher angles avoids "holes" in the data that occur because of nulls in the patterns of real antennas. From the standpoint of gain and antenna height, this file emulates 8 separate monoband antennas.

The basic antennas for each amateur band are:

80, 40 and 30 m: Horizontal half-wave dipoles, 100 ft high
20 and 17 m: 3-element Yagis, free-space gain 5.5 dBd, 100 ft high
15, 12 and 10 m: 4-element Yagis, free-space gain 7 dBd, 60 ft high

Ground characteristics at each end of path: "Average" ground

Dielectric constant: 13

Conductivity: 5 millisiemens per meter

Minimum radiation angle: 1.0°

Manmade noise level in a 1-Hz bandwidth at 3 MHz at receiver site: –148 dBW (typical for rural areas)

Required reliability: 50%, half the days of the month

Required SNR: 30 dB, for CW bandwidth (10 log 100 + 10 = 30). For SSB the required SNR would be 10 log 2100 + 10 = 43 dB, 13 dB higher.

Lowest Usable Frequency, the LUF

But have we overlooked something? Is 40 meters from 0400 to 1000 really the best choice of band and time? As we'll see shortly, NO! (Actually, it's about the worst choice!) Why is this? To comprehend the reason, we need to understand that the three curves of Figure 1A tell us *only* that, based on probabilities, the various frequencies will be supported by ionospheric propagation when indicated. But those curves tell us nothing of signal strengths. To get another piece of the best-propagation puzzle, we also need to consider the path losses between the transmitter and the receiver. A big contributor to losses is absorption in the ionosphere, particularly the D region. Some other losses are from dispersion of the transmitted energy in space and signal scattering at intermediate reflection and/or refraction points. When all these losses are added up, they can knock the signal from a 1500-W transmitter down to an S-1 level and even lower. So while the signal may be propagated via the ionosphere, it might be too weak to be heard at the receiving end of the path.

This means that at times, especially on longer paths, signals at the FOT or "optimum" frequency may be unusable because of path losses. The lowest usable frequency or LUF indicates the frequency below which signals will be too weak to be usable. The LUF may be calculated by taking many variable factors into account, such as all the path losses, the transmitter power, the transmitting and receiving antenna gains, the noise level at the receiver site, and even the bandwidth of the signal. To illustrate how some of these variables affect the LUF, consider that a weak signal from a 1.5-kW transmitter can get through the noise at times when the signal from a 1.5-W rig would never make it. Similarly, a CW signal will often get through the noise when an SSB signal will not.[3]

The New *QST* Charts

IONCAP and a few other computer programs support LUF calculations by taking all the path losses and many other variable factors into account. Figure 1B shows the new style for the *QST* charts. You'll see right away that the FOT curve of Figure 1A has been replaced by a heavy broken line. This is the LUF curve, shown as heavy and broken for distinction. The chart of Figure 1B is actually one of the 30 How's DX? charts appearing in this issue, but shown at a larger size. At first the curves that cross over each other in Figure 1B may appear confusing, but the explanation that follows should eliminate any confusion.

To use the new charts effectively, it is important to keep one thing in mind—the old adage that frequencies slightly below the MUF are always the best to use. That's because the signals are reflected back at shallow angles from the ionosphere, giving them a longer skip distance, and because they suffer the least absorption, yielding stronger signals. Depending on the day-to-day propagation conditions, the actual MUF may be near the HPF curve of the chart, it may be near the median-MUF curve of the chart, or it may be below the chart's median-MUF curve.

If you go lower in frequency from the actual MUF, the path losses increase, and with this the received signals will become weaker (all else being held equal). The lower you go in frequency, the weaker the signals become, until eventually you reach the LUF. This means that there is a frequency window for making contacts on a given path at a given time. That window includes all frequencies between the MUF and the LUF.

As propagation changes during the day the frequency window changes, and often even closes for a time on the longer paths. This happens when the MUF equals or goes below the LUF, indicated by a crossover of the curves. When the frequency window is closed, it will be difficult or impossible to make contacts on any frequency. In Figure 1B the median MUF goes below the LUF during two time periods, 0300 to 1100 and 1700 to 1900 UTC. So now, what about 40 meters between 0400 and 1000, as we originally selected from Figure 1A? No good at all, as we can now realize from Figure 1B! The LUF is higher than the median MUF for the entire period. It'd be better to get some sleep, and try at another time.

As the MUF depends on day-to-day propagation conditions, so does the LUF. As solar activity increases, so do path losses from absorption, and the lowest usable frequency becomes higher. In other words, on exceptionally good days when propagation conditions support the HPF, the LUF will also rise somewhat. So the frequency windows can shift up and down as propagation conditions change from one day to the next. But the MUF and the LUF do not always "track" each other. Another factor that greatly affects the LUF is the earth's geomagnetic activity, indicated by the K and A indices broadcast by WWV and WWVH. As these values increase, the LUF also increases. The *QST* charts assume the earth's geomagnetic activity is low.

QSO Windows

Refer again to Figure 1B. With the preceding information, we now see that on an average propagation day there will be two frequency windows during the forecast month for the Mid-USA to Central Asia path, from 1100 to 1600 and from 1900 to 0300 UTC. With the new charts, finding the best times and amateur bands for making schedules or for seeking DX contacts is simply a matter of selecting a big frequency window from the chart (a large separation

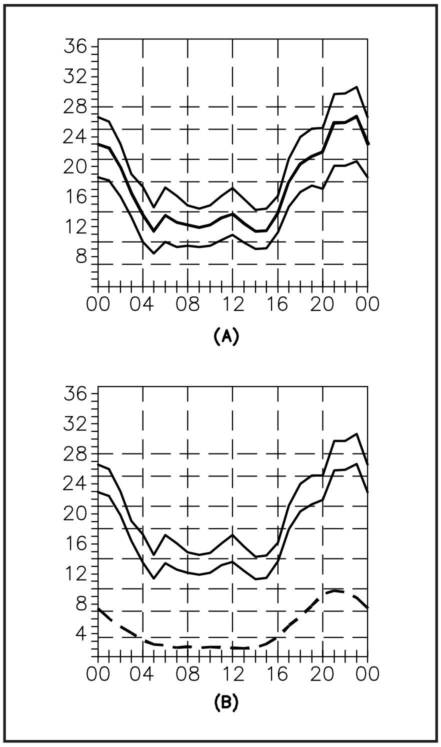

Figure 2—Curves showing propagation probabilities from Hawaii to the West Coast for mid-October to mid-November. The horizontal axis indicates Coordinated Universal Time (UTC) and the vertical axis frequency in MHz. The curves at **A** show HPF/median MUF/FOT, while **B** shows the new chart style with HPF/median MUF/LUF curves. Note in **B** that the frequency window is open around the clock. See text for determining the FOT from the new chart style.

between the median-MUF and the LUF curves) and choosing the band nearest the median MUF—a QSO window, if you will. We see in Figure 1B that on average there will be a brief 20-meter band opening around 1400 UTC. (On exceptionally good days this may develop into a 17-meter band opening from 1400 to 1800.) We also see that the chances for a 30-meter band opening are good from 2200 to 0200 UTC. The best propagation during the 24-hour period is likely to be during the brief 20-meter QSO window at 1400, as the LUF is below 12 MHz.

If you're looking for a longer QSO window, then try 30 meters from 2300 to 2400; the median MUF is not far above 10 MHz and the predicted LUF is below 9 MHz. If you are making a schedule, it'd be wise to have alternative bands to allow for short-term propagation changes. Twenty meters between 2300 and 2400 would be a good second choice, as the HPF is above the 20-meter frequencies.

Among all the charts in the How's DX? column you'll see several paths where the frequency window is open all day long. The Hawaii to West Coast path is one example, shown in Figure 2B. Choosing the best band for use at a particular time of day is simple; just take the one nearest the median-MUF curve, keeping in mind that day-to-day changes may have some effect.

FOT Values from the New Charts

Just because the FOT curves will no longer be appearing in *QST*, you should not assume the FOT information has no value. Indeed, the FOT will almost always provide consistent "armchair copy" on short paths, and on any path when the FOT is significantly above the LUF. The FOT information is very helpful in point-to-point communication where 90% or higher reliability is required. Say that you live on the West Coast (San Francisco) and want to maintain continuous reliable contact with Hawaii (Honolulu) for an extended period of time. Figure 2 shows the probabilities for this path. Figure 2B indicates the frequency window is open all day long with the LUF significantly below the median MUF, so amateur bands near the FOT would be a wise choice.

Even though the FOT data is not included in the new chart, you can still obtain FOT values to a good approximation by taking 80% of the median MUF.[4] For example, note the median MUF in Figure 2B at 0600 UTC. The value there is 13.0 MHz. Taking 80%, FOT = $13.0 \times 0.8 = 10.4$ MHz. For comparison of this result, see the FOT value plotted in Figure 2A. At 0600, IONCAP predicts the FOT will be 10.0 MHz.

Let's look at another time, 1600 UTC. The median MUF is 14.0 MHz. The approximation is FOT = $14.0 \times 0.8 = 11.2$ MHz, whereas the value from IONCAP is about 11.5 MHz. Although there may be some slight difference between this approximation and more precise calculations, the appropriate amateur band should be easy to discern from the approximations. For this path, Hawaii to West Coast, the FOT results indicate the 30-meter band should provide communications for at least 90% or 27 days of the prediction period from about 0400 to 1600 UTC.

Specific Path Terminal Points

The 30 charts in the How's DX? column cover as many paths as possible within a reasonable amount of page space for all the readers of *QST*. For a particular geographic area, the number of those to use is reduced. If you're in the western, central or eastern part of the US you'll find charts to South America, Central Asia, Southern Africa, Western Europe, Eastern Europe, Japan and Australia. There are two charts to South Pacific from the US, Mid-USA and East Coast, and one chart from the West Coast to the Caribbean. In addition, there are two charts for Alaska showing probabilities for the East Coast and Western Europe, and three charts for Hawaii to the West Coast, East Coast, and Western Europe. A chart for the East Coast to West Coast completes the set.

In earlier issues of *QST* a chart was included for the West Coast to the South Pacific. Beginning with this issue, that chart has been replaced by the popular path, Hawaii to the West Coast. If you are interested in data for the the West Coast to the South Pacific, you can linearly interpolate the sets of curves for Hawaii to the West Coast and the West Coast to Australia. The results will be quite accurate, as the bearings are essentially identical and Pago Pago (the South Pacific terminal point) is very close to being halfway between Hawaii and Australia.

Another change in the charts is the terminal point in Australia. Now the charts use Sydney, rather than the former Melbourne. This change better covers New Zealand, and also facilitates the interpolation for West Coast to South Pacific, mentioned in the previous paragraph. Another minor change is a name change only for the path from the Caribbean to the West Coast, formerly shown as Puerto Rico to the West Coast.

From these statements it becomes obvious that the labels for the charts give generalized geographic areas. The actual locations for all terminal points are listed in Table 1. If you are located some distance from an actual terminal point, you can make some correction based on latitude. The general rule is that the higher the latitude, the lower will be the median MUF.

IONCAP Data

The results from all IONCAP calculations pertain to a calendar month that is specified when the program is run. Because the *QST* prediction period straddles two calendar months, some extra steps are taken at ARRL Headquarters to provide information for the *QST* prediction period. Two sets of calculations are run—one for the first calendar month and one for the second. The means of the results (averages, in common parlance) from the two months are then used to prepare the charts.

The technical data that goes into IONCAP for the calculations are summarized in Table 2. The legal power limit (1500 W) for the calculations is used, not because everyone will be running this power, but because the LUF can be adjusted upward for lower levels. Similarly for the antenna gains; the LUF can be adjusted upward if you have antennas with lower gains than those used for the calculations, or adjusted downward if you have super antennas with greater gains.

Short-Term Propagation Changes

As mentioned previously, the actual MUF may be near the HPF curve of the chart, it may be near the median-MUF curve of the chart, or it may be below the chart's median-MUF curve. To get a report of current propagation conditions, listen to the WWV propagation broadcasts at 18 minutes past the hour or WWVH at 45 minutes past.[5] Daily observed 2800-MHz solar flux values are given in the broadcasts. Compare this number with that in the caption for the How's DX? curves. If the flux number for the day is higher than that used to prepare the charts, the frequency windows will generally shift to higher frequencies. The higher frequency bands will usually open earlier and close later than predicted. Conversely, if the daily flux value is lower than that used for the charts, the frequency windows will be lower; the higher frequencies will open later and close earlier than indicated. Higher frequency bands showing only brief openings in the charts may not open at all.

Also pay attention to the A and K indices, indicators of the Earth's geomagnetic activity as measured at Boulder, Colorado. The A index is calculated from the previous day's K index values,[6] so it tells you mainly how yesterday was. As the A index rises, so does the LUF. The K index is updated every 3 hours in the WWV/WWVH broadcasts. The absolute values are meaningful, with values of 3 or 4 and above indicating unsettled geomagnetic conditions, but the trend of the 3-hour periods also conveys useful information. Rising values mean the LUF will be going higher still, while falling values mean the LUF will be dropping.

Another way to learn about current propagation conditions is to spend a few moments tuning the bands and comparing what you hear against appropriate charts in *QST*. Observations for paths to not-too-distant locations from your area can be applied to the really long-haul paths. Listen for areas where there is usually a lot of amateur activity.

If a chart says you should have a good QSO window to an area less than roughly 5000 miles away and signals are booming in from that area, this means conditions at the time are close to those predicted in the charts. On the other hand, if you hear only a few weak signals from there, chances are that the LUF is higher than predicted. If you hear no signals at all from there, then either the LUF is significantly higher or else the MUF is lower than predicted. A way to help determine which is to listen on the next-higher frequency band. If you hear any signals from the same area on this band, then the LUF is higher; if you again hear nothing from the area, the MUF could be lower, but also the LUF could be considerably higher because of geomagnetic activity. This all assumes the *QST* chart indicates a good QSO window. If you hear very little or no activity on any bands at times when the charts indicate good QSO windows, then the LUF is considerably higher than predicted.

In Summary

With the LUF curves present in the monthly How's DX? charts, it's easy to see the very best times and bands for making schedules or for seeking DX contacts—just pick the time when the widest gap or frequency window exists between the MUF and the LUF curves (with the LUF curve on the bottom!), and choose the band nearest the MUF.

It's also easy to see what paths will be difficult, no matter what the time of day or what band is used. Knowing when none of the amateur bands may be usable becomes important on the longer paths.

Is the band dead, or is there simply no activity? With *QST*'s new monthly propagation charts and a knowledge of current propagation conditions, now you can determine the answer to that question.

Notes

1 IONCAP was written by the Institute for Telecommunication Sciences and its predecessors in the US Department of Commerce. For more information see J. Hall, "Propagation Predictions and Personal Computers," Technical Correspondence, *QST*, Dec 1990, pp 58-59.

2 See D. Sumner, "Chart Your Way to Better DX," *QST*, Jan 1977, pp 58-60. (HPF curves were not included during the first 8 months of chart appearance in *QST*.)

3 For additional information on the LUF and some practical examples, see J. Hall, "Propagation Predictions for HF—A New Look," *QST*, Feb 1992, pp 48-50.

4 The rule for earlier manual methods of predicting propagation was to take 85% of the predicted MUF to obtain the FOT, but taking 80% of the median MUF from the *QST* charts produces results closer to those of IONCAP.

5 For additional information on interpreting the data from the broadcasts, see R. Healy, "Propagation Broadcasts and Forecasts Demystified," *QST*, Nov 1991, pp 20-24.

6 G. Jacobs and T. J. Cohen, *The Shortwave Propagation Handbook*, 2nd ed. (Hicksville, NY: *CQ* Publishing, Inc, 1982), p 110.