HF SYSTEM SIMULATION TECHNIQUES

by
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BRIEFING CONTENT

- WHY SIMULATION?
- SYSTEM FACTORS.
- SYSTEM PREDICTIONS.

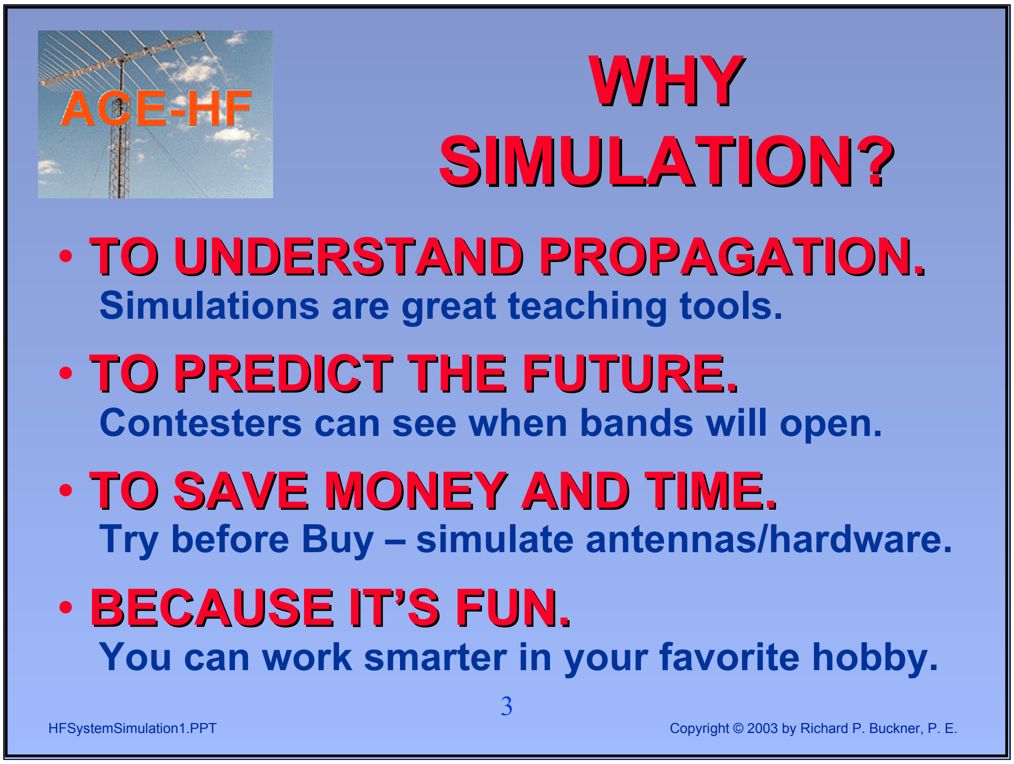
Thanks for your interest in ACE-HF!

This briefing discusses the simulation of HF radio systems and uses illustrations from the ACE-HF System Simulation and Visualization software, Version 2. More information about ACE-HF may be found at http://www.acehf.com.

The briefing focuses first on the importance of making correct HF system simulations and states some reasons for why simulations should be made.

HF system factors to be considered are then detailed.

Finally, techniques recommended for making HF system predictions are given.

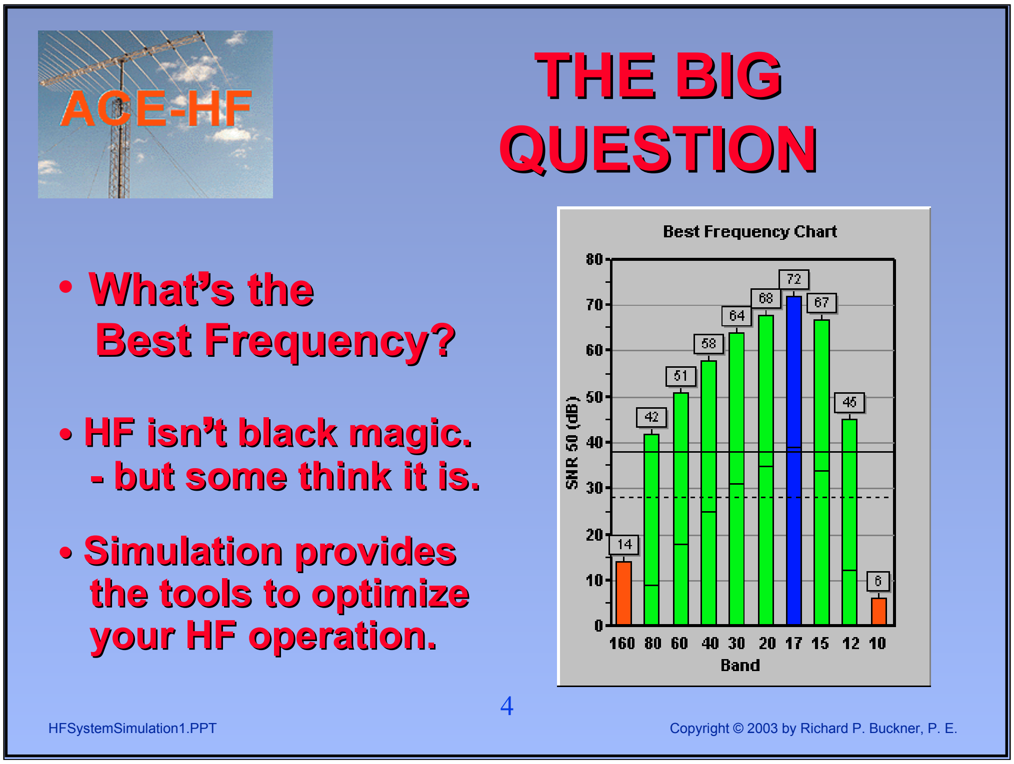


The primary reason for simulating your system is to better understand HF ionospheric propagation and the effect that propagation has on communication circuits. Computer simulations that include propagation effects are great teaching tools. Young hams just entering the hobby are often confused about HF operation, and the creation of a proper simulation can help the learning process.

System simulations give the operator the ability to make future predictions – at future hours and/or months. Ham contesters and DX operators value such simulations because they can see in advance when their favorite bands will be open and can support radio contacts.

A good simulation also permits the ham operator to see the effects of different equipment selections. For example, he might simulate the effects on transmission coverage of a new antenna purchase he is planning – a try before buy experience.

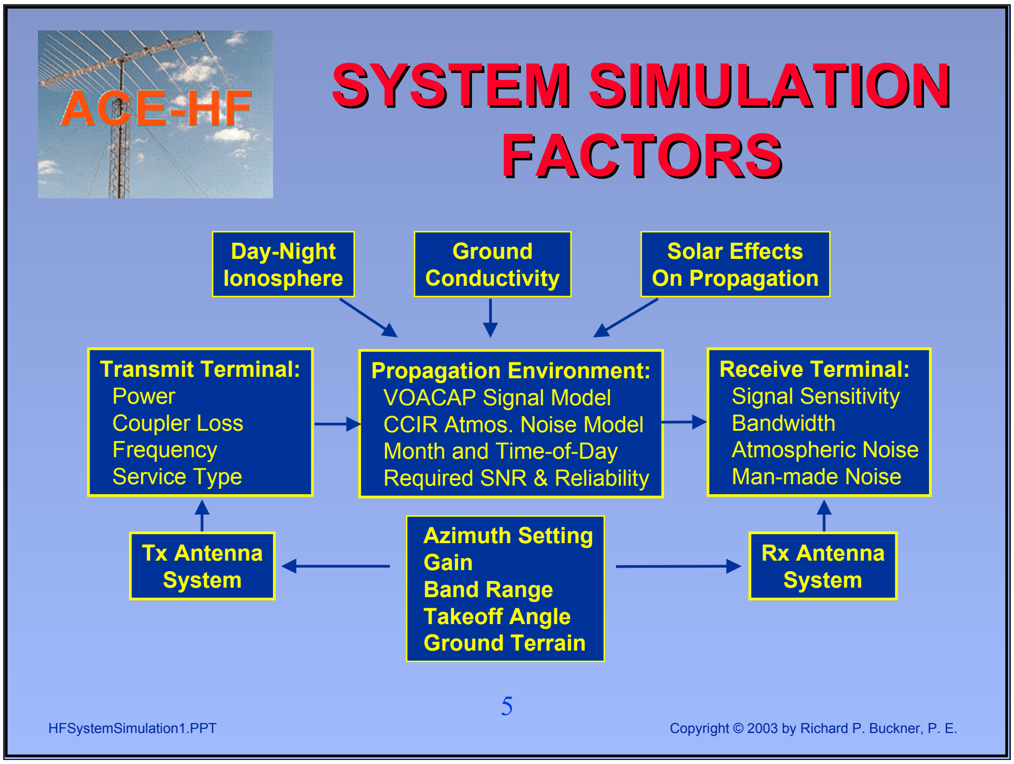
Finally, HF simulations are fun to work with. They permit the ham to work smarter and are another aspect of the hobby that provides great enjoyment.



HF propagation is primarily skywave, utilizing reflections from the ionosphere, and ionospheric conditions are extremely variable, changing from hour-to-hour. Each HF frequency channel experiences different variations; a 4-MHz channel might be *open* when 14-MHz is *closed*.

HF isn't black magic, but sometimes it seems to be when one listens on a ham band and finds it dead. Usually, the reason is that the propagation medium simply doesn't support the transmission at the current time-of-day. HF simulations permit the user to find the best frequency for each planned QSO and thus increase the chances for a good contact.

Simulation provides the tools one needs to optimize the ham HF experience. No more calling in the blind – one can see in advance when a favorite band is open.



It is important to simulate the entire end-to-end system, rather than the propagation channel alone. This chart shows that emphasis must be placed on simulating all factors of the system.

While propagation predictions include the VOACAP signal and atmospheric noise models, the factors also include those of the transmit and receive terminals. Each factor shown in the chart affects the circuit predictions, and must be correctly specified for a correct simulation to be made.

In the simulations, correct antenna modeling is always emphasized. The user may select existing models (such as those from the standard antenna lists of VOACAP), or may specify his own. Since patterns generated by different antennas vary from location to location, it is important to fine-tune such models for local ground conductivity, dielectric constant and terrain variation factors.

NEED FOR PROPAGATION PREDICTIONS

HF SYSTEM OPERATIONAL PRIORITIES		
FACTOR	**TYPICAL CHANGE**	**EQUIVALENT POWER INCREASE**
TRANSMIT POWER	**0 to 10 dB**	**X 10**
ANTENNA GAIN	**0 to 20 dB**	**X 100**
PROPAGATION	**0 to 60 dB**	**X 1,000,000**

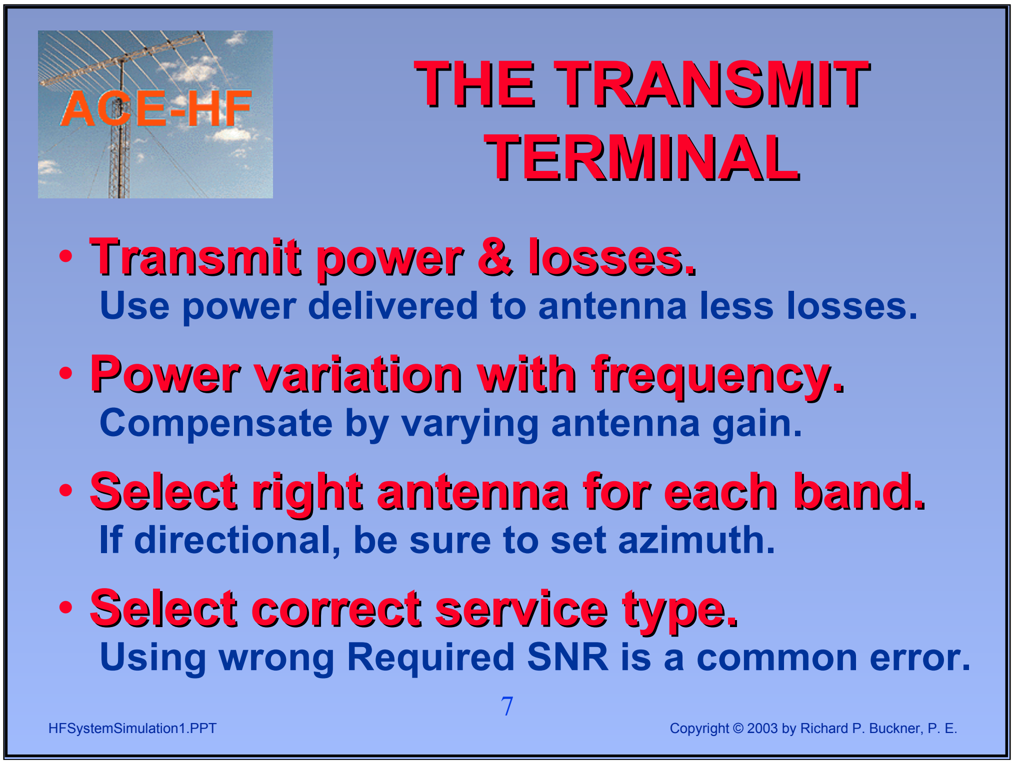
Courtesy of Mr. George Lane, Lane Consultant

This chart shows why HF propagation predictions are always needed, whether transmitter over one circuit or operating a large network of circuits.

Of all the components of an HF system, the variations in the propagation medium itself are the most severe. Unlike other bands, HF propagation losses can typically change over a 60-dB range, which is equivalent to changing a station's transmitter power by a factor of one million.

Contrast this with other HF system components, where it is common to increase transmitter power by perhaps 10 dB, say from 100 to 1000 watts. Even gains from highly directional antennas rarely exceed 20 dB.

It is clear that propagation variations control the success or failure of an HF circuit.



The chart lists some items to check when simulating the HF transmit terminal.

First, be sure to correctly specify transmitter power. The simulation programs assume that the stated power is that delivered to the antenna. Thus, the transmitter's output power level should be adjusted by any losses in transmission lines or antenna couplers.

Power may vary with frequency also. In this case, if the power differences at different bands are significant – greater than a few dB – one should compensate by adjusting antenna gain.

Be sure to select the right antenna for each band. Most simulation programs include the ability to select several antenna types and to apply them to ranges of bands. If one or more of the antennas is directional, don't forget to set the azimuth within the simulation so the antenna is pointed in the direction you want.

Finally, be sure to select the correct service type in your simulation. For example SSB service will have a different Required SNR than that of CW.

THE RECEIVE TERMINAL

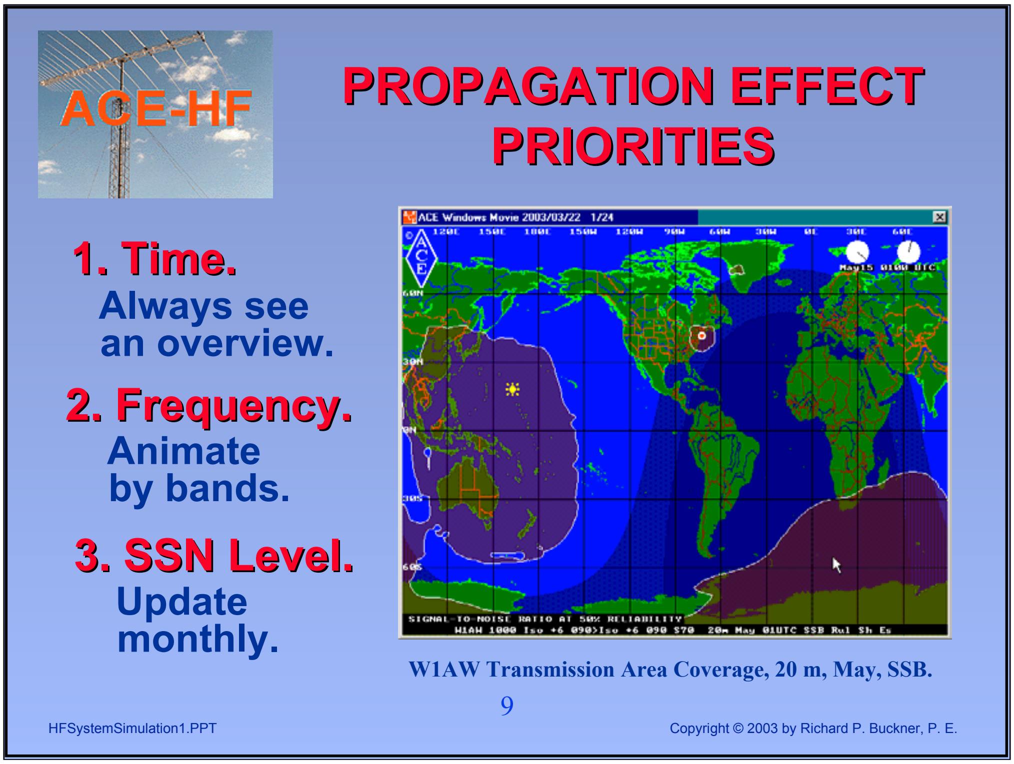
- **Know your contact.**
  Try to specify his Tx power and antenna.
- **What's the man-made noise level?**
  Is he/she in the country or in a large city?
- **Accurately model distant antenna.**
  Is it pointed at you?
- **If in doubt . . . .**
  Use an Isotropic antenna with + 6 dB gain.

At the receive end of the circuit, the problem is somewhat different, because hams often have no knowledge of a new contact's station. If possible, however, try to at least specify his/or her antenna type.

Also, give consideration to the distant contact's QTH. Is he or she is a heavily-industrialized city where man-made noise would be expected to be higher, or is the distant station in the country. Remember that the man-made noise level of the simulation applies to the distant receive station, not to your transmit station.

If you can gather information about the distant station, focus on the antenna. Is it a directional antenna? If so, try to determine if it is pointed at your station when you simulate the circuit.

If in doubt, specify an isotropic antenna for the distant station. Such antennas are theoretical radiators that emit power in all directions. Set the isotropic antenna gain at about +6 dB, as that level simulates the typical ham antenna.

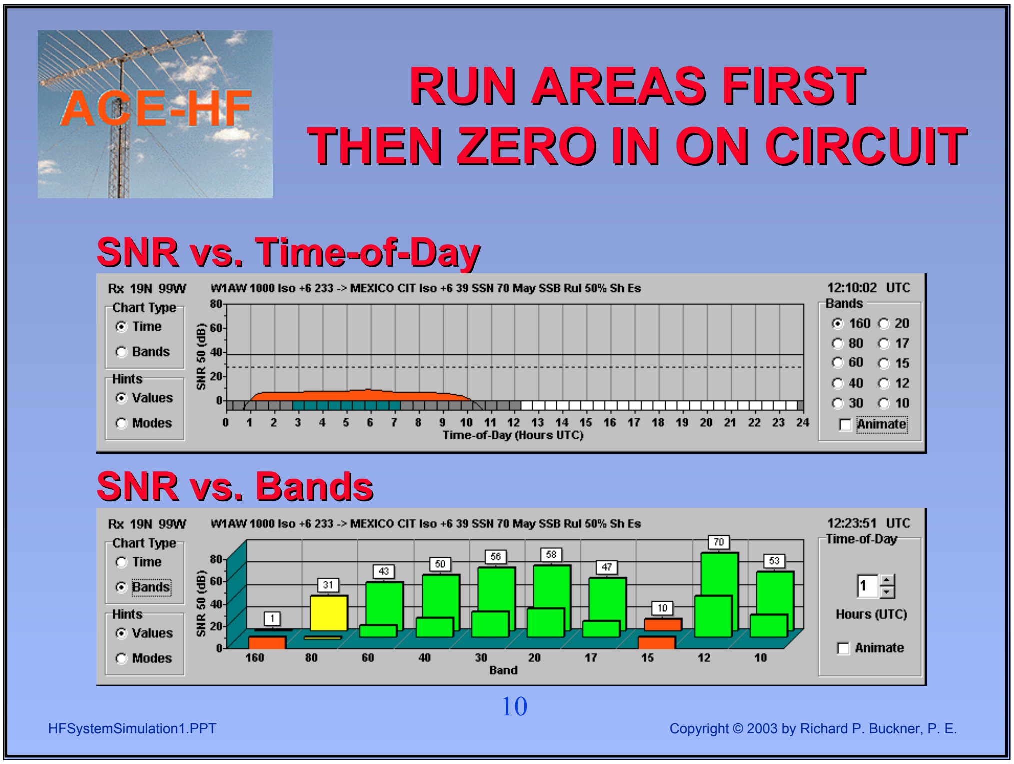


Once you have correctly simulated the system, take a look at predicted area coverage from your station. As you explore the effects of the simulation, remember the most important effects on coverage:

1. Time is the most important factor affecting station coverage. Always animate such displays as a function of time-of-day when you can. Sometimes astonishing effects of the day's passage may be seen and understood through such displays.

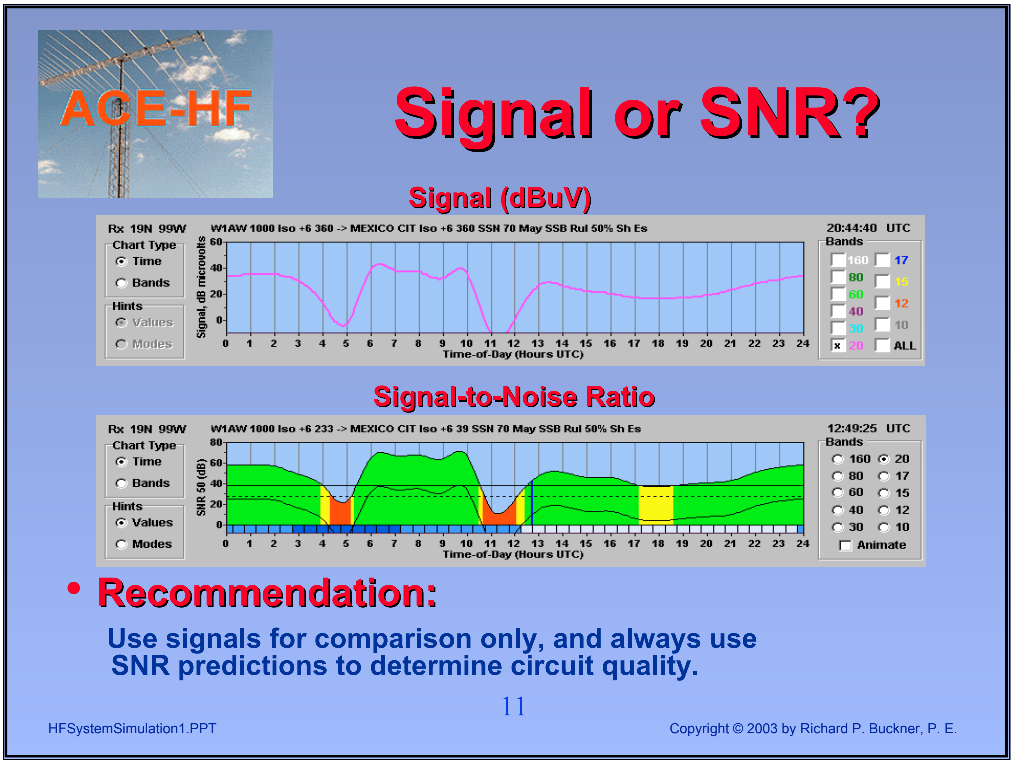
2. Frequency is the next most important factor. If possible, animate the coverage display as a function of the various ham bands. Remarkable differences in coverage to various world areas will be shown by such displays.

3. The final factor affecting station coverage is the Smoothed Sunspot Number (SSN). Be sure to update your simulation monthly by specifying the current SSN estimate.



Charts such as these are instructive once the coverage area from the station has been understood. Point-to-point circuit graphs such as signal-to-noise ratio vs. time-of-day and frequency can be animated through their ranges to better understand when the bands will be open for a particular circuit.

SNR is the primary measure of circuit quality and is used to define whether each frequency band is Open (green) or Closed (red).

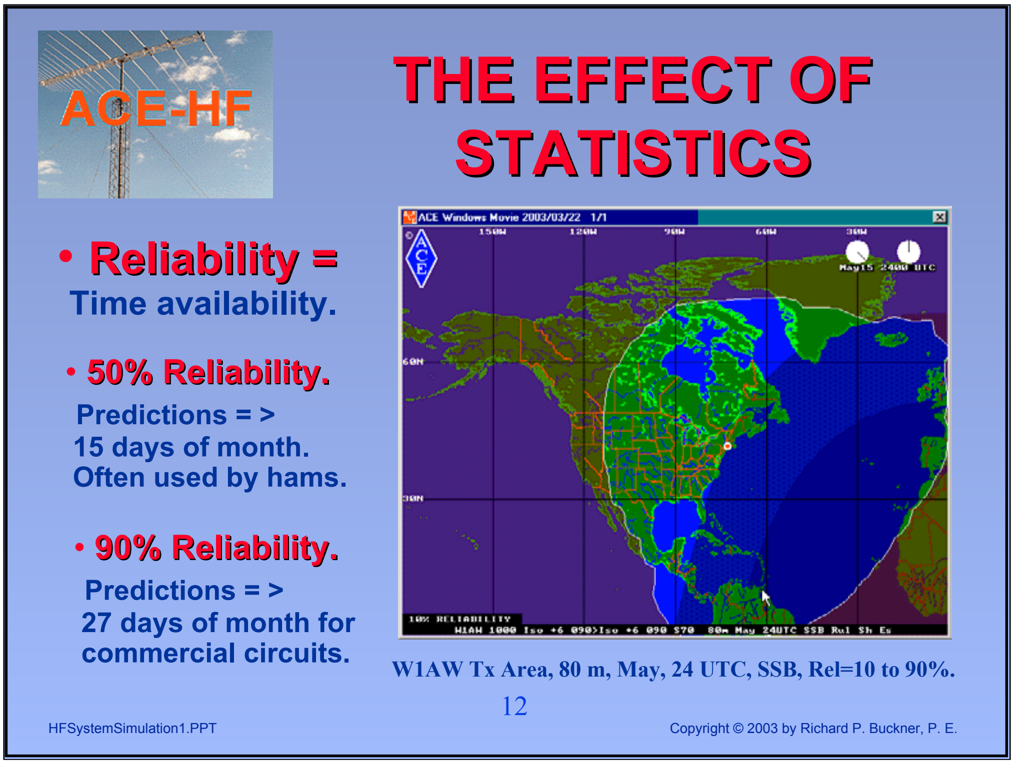


Simulation charts can display many variables of the prediction, and a common question is whether signal or SNR levels should be used as a measure of circuit quality.

It is natural to look at signal predictions, because most ham receivers have S-meters, and it is common practice to compare relative receive signal levels from the various stations.

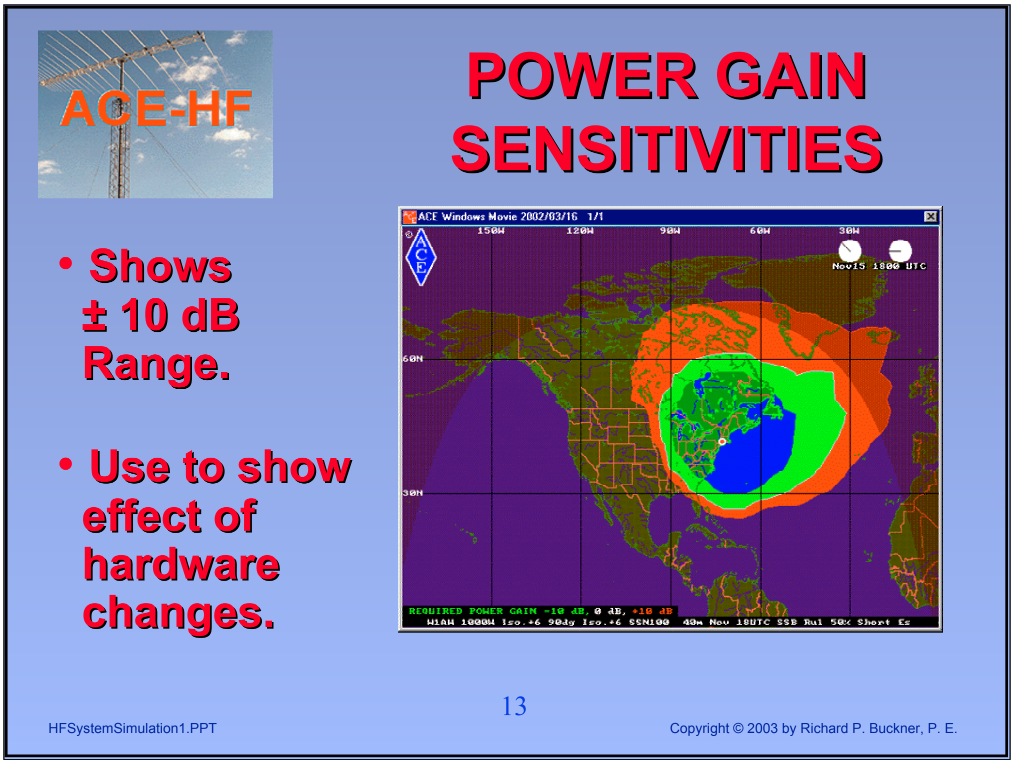
However, it is recommended that signal predictions be used for comparison only since they are usually only hypothetical levels that assume the arriving signal has been transferred to the receiver without any loss.

The simulation's signal and noise levels used for SNR predictions are much more reliable, because they are treated as a ratio that remains unchanged by individual station factors.



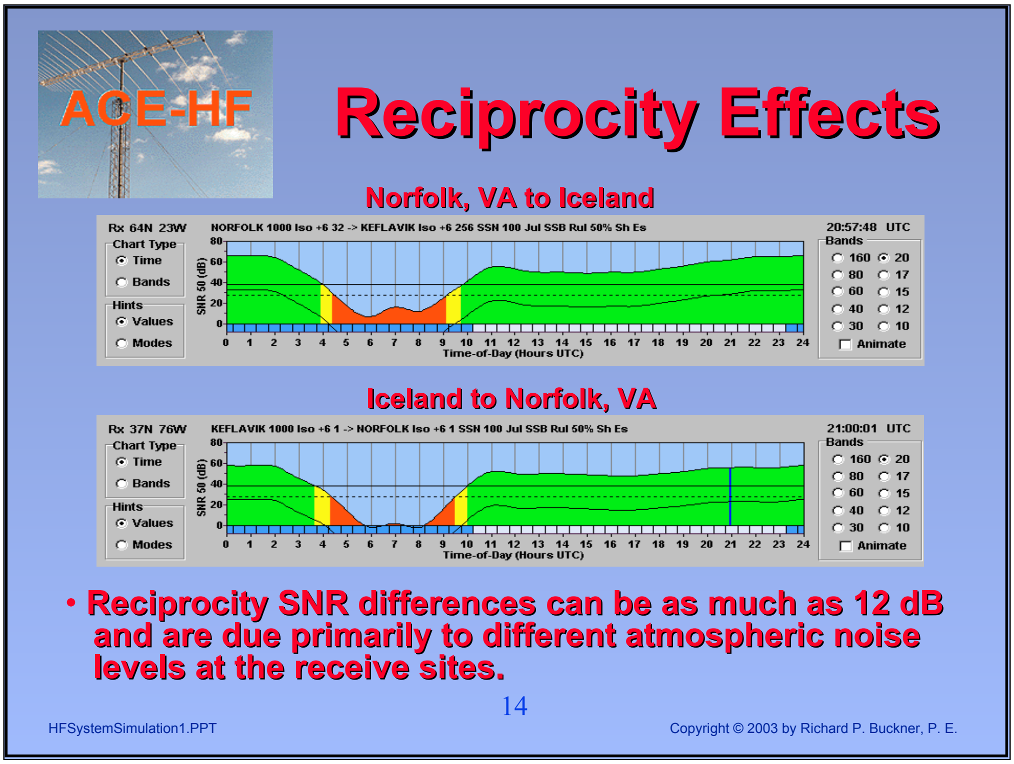
In HF, Reliability means the predicted monthly Time Availability for each hourly computation. For example, 50% Reliability is a monthly median level and means that the circuit would be available as predicted (or better) only 15 days of a 30-day month.

Here the simulation's statistical factors come into play. When a higher required reliability is specified, those factors are included in the computations and the result is a more conservative simulation. For example, a 90% reliability means that the circuit would be as predicted (or better) during 27 days of a 30-day month. In an area coverage map, the more conservative coverage area is smaller.



The simulation's area coverage displays can also show the effect of power gain. The chart shows those sensitivities over a ±10 dB range by the green and red areas. Increasing transmitter power or transmit antenna gain by 10 dB would result in the larger area coverage shown by the red area. Decreasing those factors would result in the limit of the smaller, green, area.

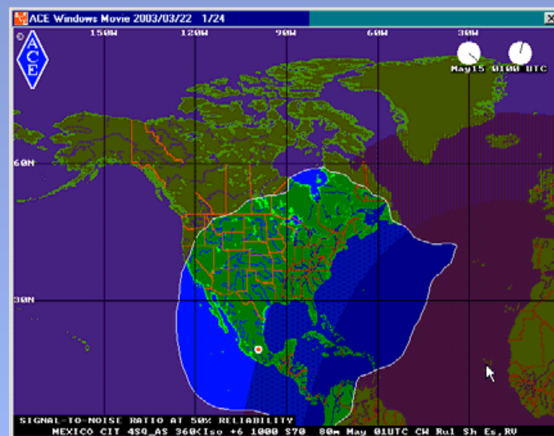
Such displays may be used to show the effect of potential changes in the station's hardware or power settings.



HF circuit predictions are not reciprocal. Historically, ionospheric signal propagation has been considered to be essentially the same in both directions along a given path, and excluding short-term changes in the ionosphere, this is true within a few decibels. However, when predicted SNR is considered, the circuits are not reciprocal.

In a recent ACE-HF study performed for the U. S. Navy, circuits examined within the Atlantic area showed a directional difference of as much as 12 dB in received SNR. The source of this reciprocity failure was determined to be the different atmospheric noise levels at either end of the circuits. Such atmospheric noise levels result from lightning flashes, which in the summertime are concentrated within the thunderstorms that exist in the Caribbean area.

RECEPTION AREA PREDICTIONS



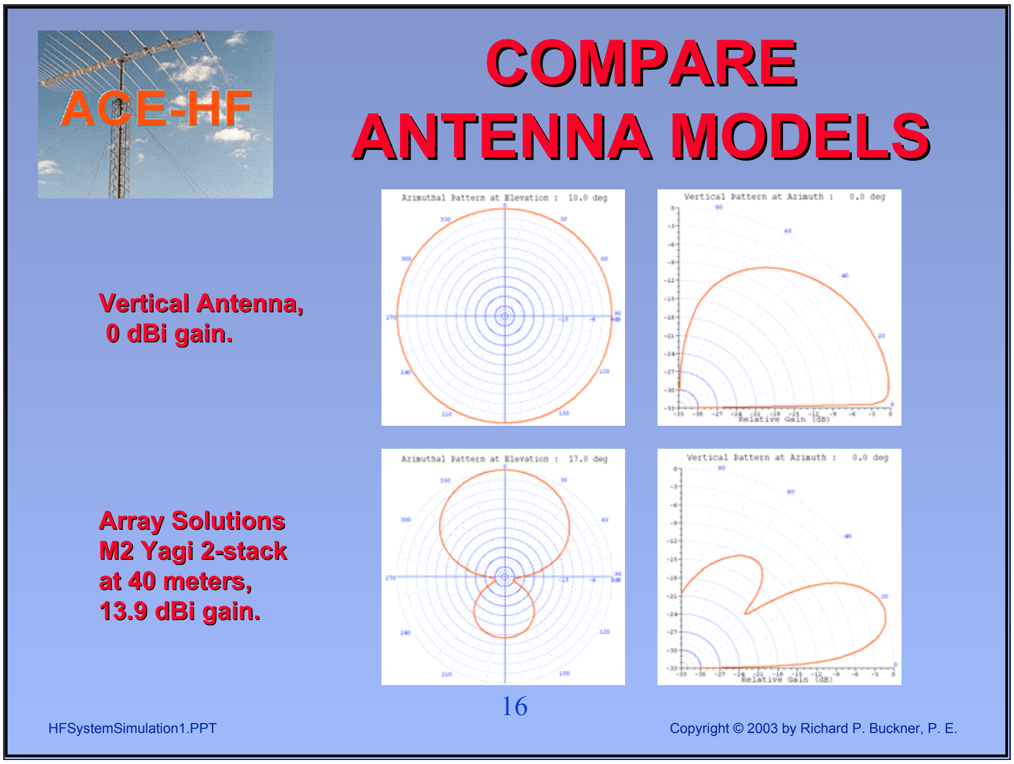
- Use to show potential Tx sites that can be heard from a specified receive location.
- Coverage varies with noise level at receive site.

Mexico City Reception Area, 80 m, May, SSB, Array Solutions 4-square Vertical Array, Az 360 dg.

Area coverage simulations can show transmission areas or reception areas. The latter type is shown in this chart.

Reception area coverage is used to show potential transmitter sites that can be received from a specified receive location. In this example, SSB reception on 80 meters at a Mexico City station is illustrated. The animation shows that transmissions from all 48 states of the continental U.S. could be received, but only at certain times-of-day.

This example uses an Array Solutions four-square vertical array antenna at Mexico City. Such antennas have a cardioid pattern, which in this case is pointed due North.

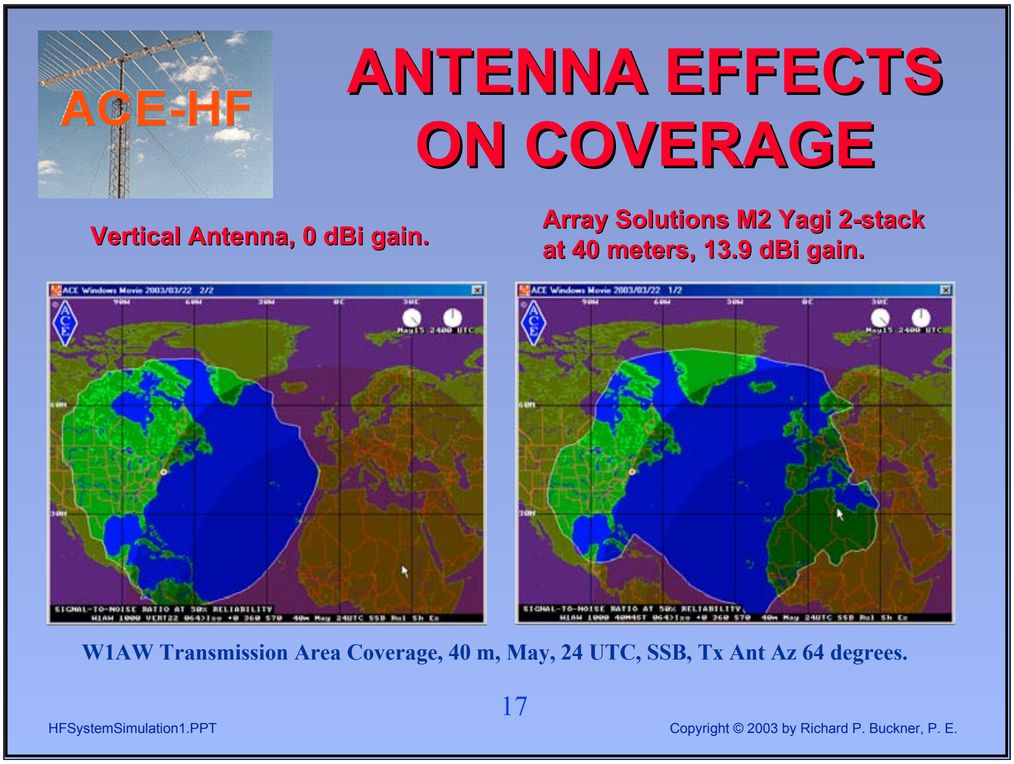


HF system simulations may be used to compare the effects of using different antenna types.

In this chart, a common vertical antenna is compared with an Array Solutions two-stack Yagi at 40 meters.

The Yagi stack is seen to concentrate most of its gain in one horizontal direction. The pattern shows that most emission is also directed at a fairly low elevation angle – in this case a little less than 20 degrees.

One would expect the higher-gain antenna to result in a larger coverage area from the station.

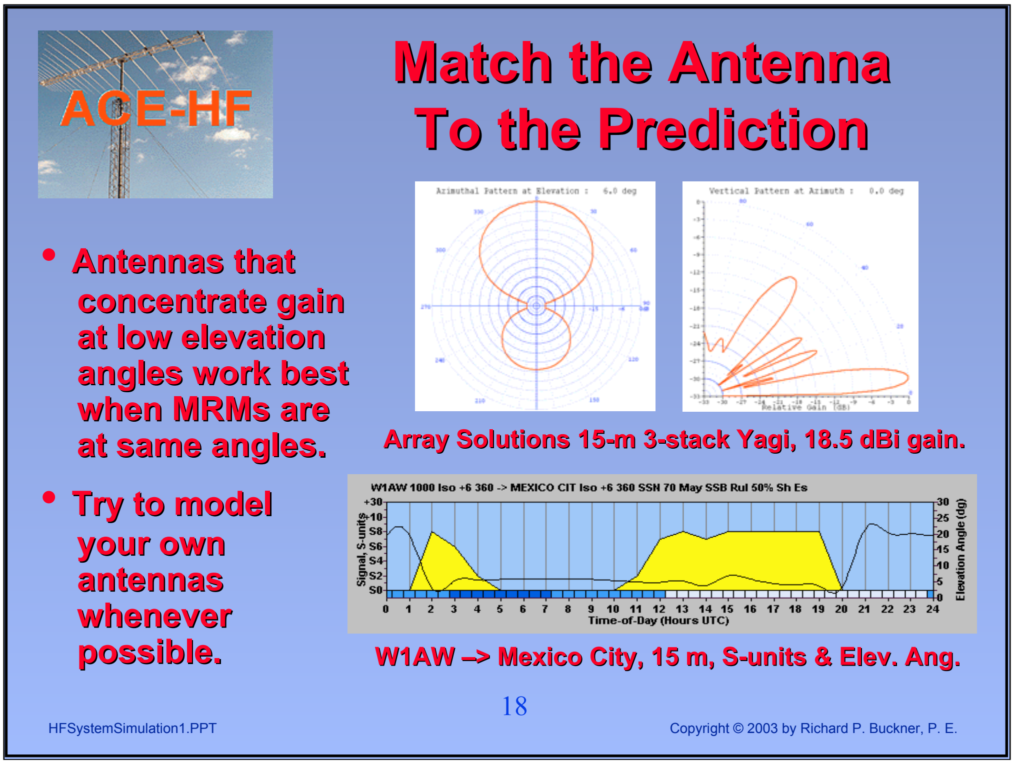


Here we see area coverage predictions from the two antenna models of the previous chart.

As expected, the vertical antenna at W1AW has a fairly circular pattern, although coverage favors the ocean area. This is due to a combination of factors: There is more ground loss in signals over land, and the approaching nighttime area to the right favors enhanced propagation in that direction.

When the Yagi stack is used, emission is concentrated to the East in this example where the azimuth has been set for 64 degrees.

The comparison shows that the additional antenna gain of nearly 20 dB increases coverage to include most of Europe and a large part of North Africa, whereas coverage with the vertical antenna did not extend past the Atlantic area at this time-of-day (24 UTC).

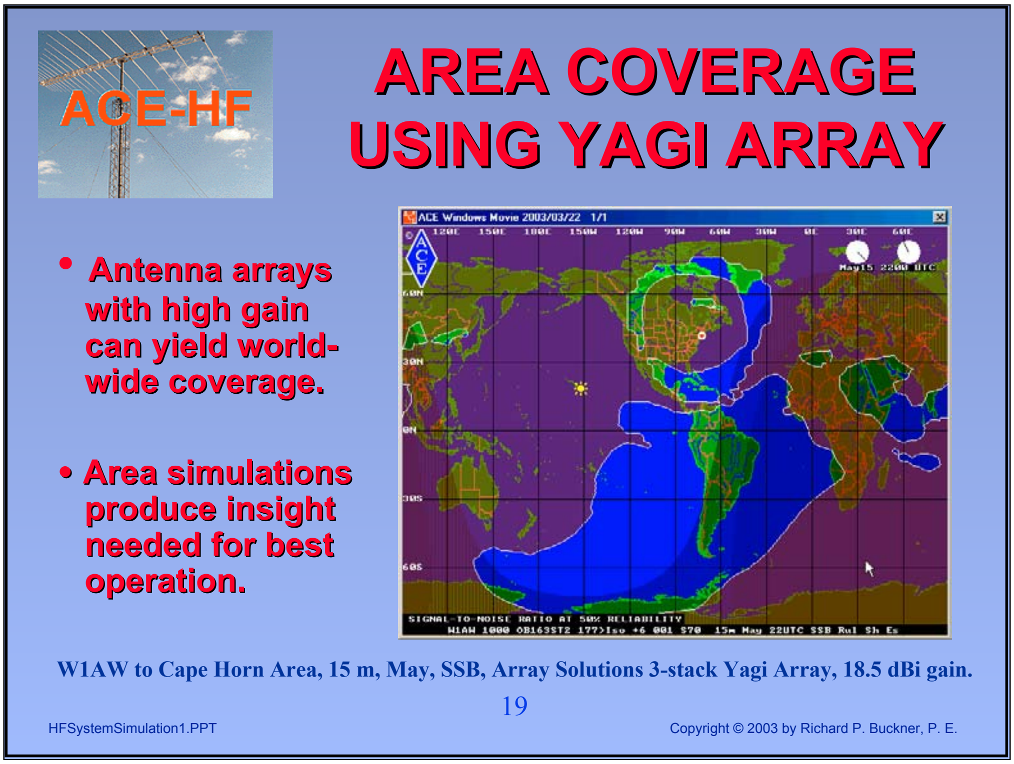


It is always important to consider to match the antenna's pattern to the simulation's elevation angle prediction for best performance.

In this example, an Array Solutions three-stack 15 meter Yagi antenna is used. This antenna has a remarkable emission characteristic in the vertical plane – nearly 20 dB gain is concentrated at a very low take-off (elevation) angle, about 4 to 6 degrees in this case.

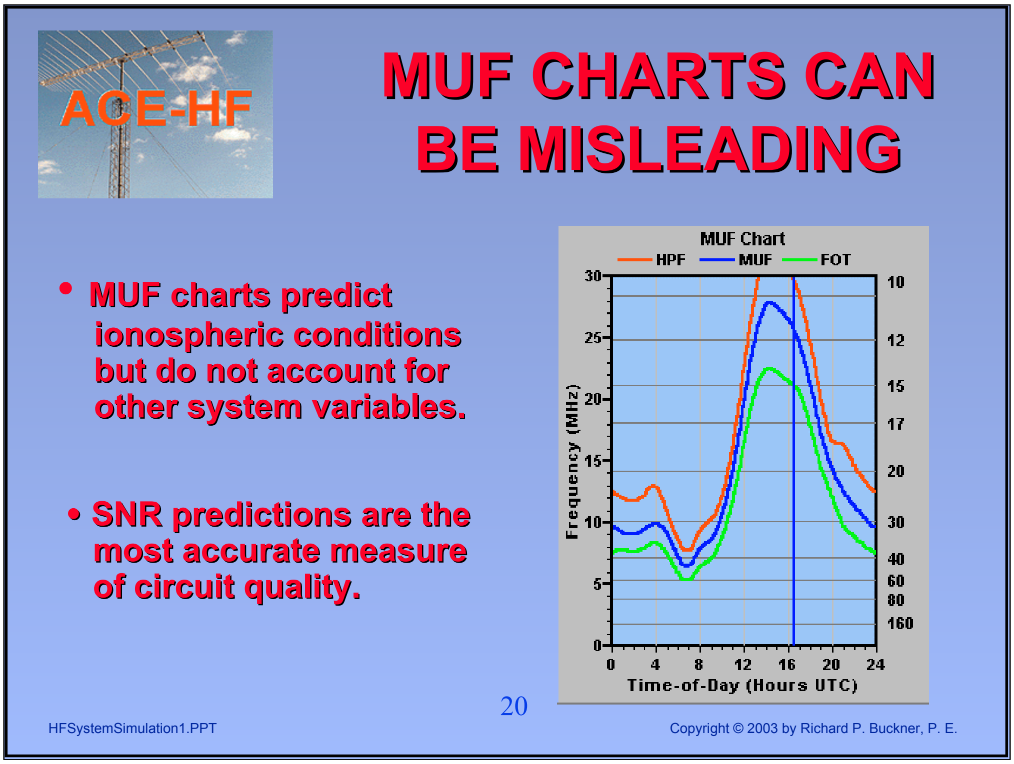
The simulation of a circuit from W1AW to Mexico City shows that the predicted elevation angle of the Most Reliable propagation Mode (MRM) is about 6 degrees for a large part of the day.

Since the antenna's emission matches very well to the predicted MRM, performance of this arrangement should be very good.



Indeed, the area coverage plot for the three-stack Yagi of the previous chart shows remarkable coverage in this illustration, where the antenna was pointed at Cape Horn.

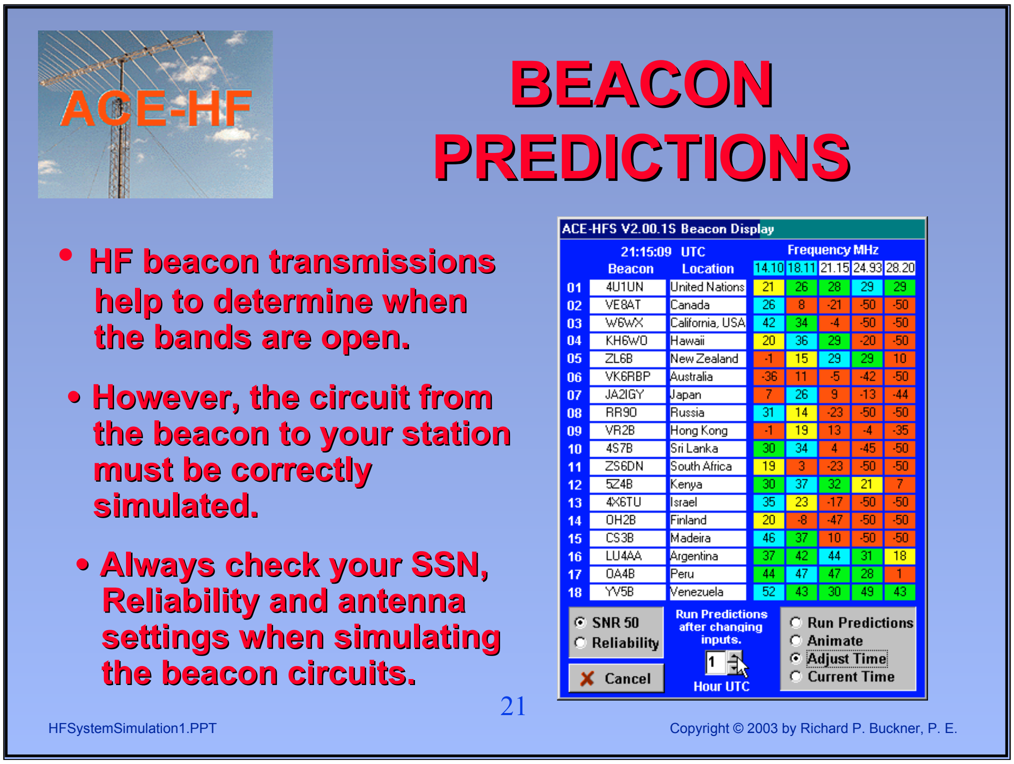
Such area simulations yield great insight as to the system configuration needed for best station operation.



Use of traditional HF MUF charts can be misleading when used in conjunction with system simulations.

MUF (maximum usable frequency) charts accurately predict ionospheric conditions, but do not account for the other system variables, such as atmospheric noise, antenna pattern differences, etc.

For this reason, SNR predictions remain as the most accurate measure of circuit quality in any HF simulation.



Another useful system simulation tool is a prediction from one of the NCDXF/IARU International Beacon Network stations. Such predictions help one to understand when the bands might be open to each of the 18 countries of the network.

However, the circuit from each beacon station must be carefully simulated. The predictions vary by system factors such as SSN, required reliability, and the antennas modeled at your receive station.

Always check those factors when using the beacon simulations for most accurate duplication of the received beacon signals.

USE SNR AND REL SUMMARY CHARTS

- Summary charts provide a good overview of the HF end-to-end system. They are similar to MUF charts but include all system factors.
- Use summary charts to see circuit conditions at a glance.

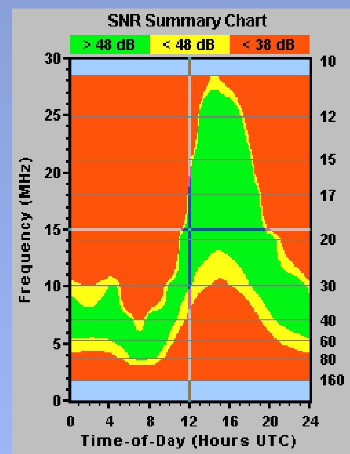
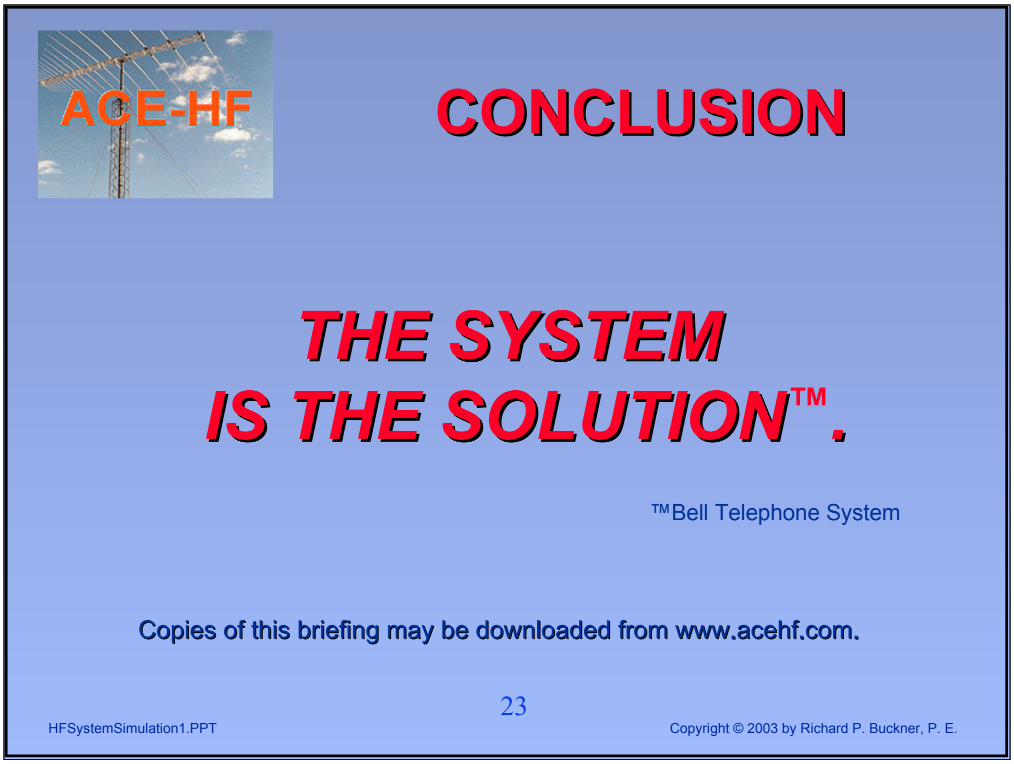


Chart concept suggested by George Lane.

Summary charts such as the one shown here provide a good overview of the end-to-end HF system. Their appearance is similar to the MUF charts, but in this case they include the effects of all system factors.

This chart, incidentally, was devised by Mr. George Lane, the VOACAP sponsor, during the time when Mr. Lane was working with U.S. Army HF communications.

The chart enables circuit conditions to be seen at a glance, and is a good way to summarize the system's integrity at any frequency or time-of-day.



Whenever you operate your ham station, always remember that its performance and your chances for making assured contacts depend on all factors of the system being correctly adjusted.

A system simulation is a good way to optimize you operation and to have more success with the ham hobby.