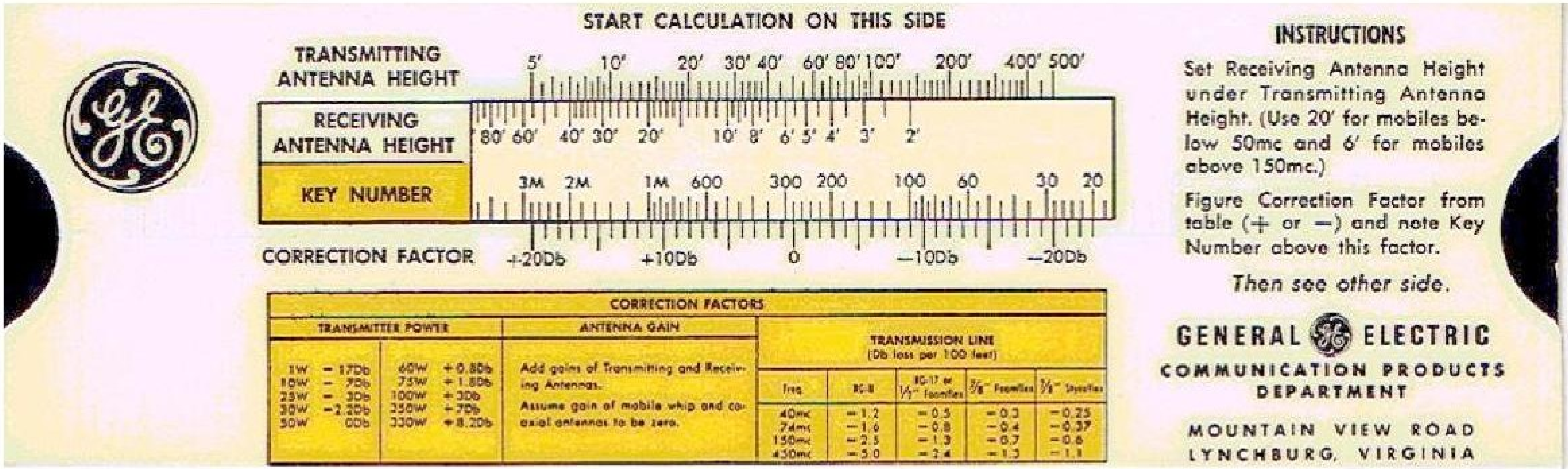
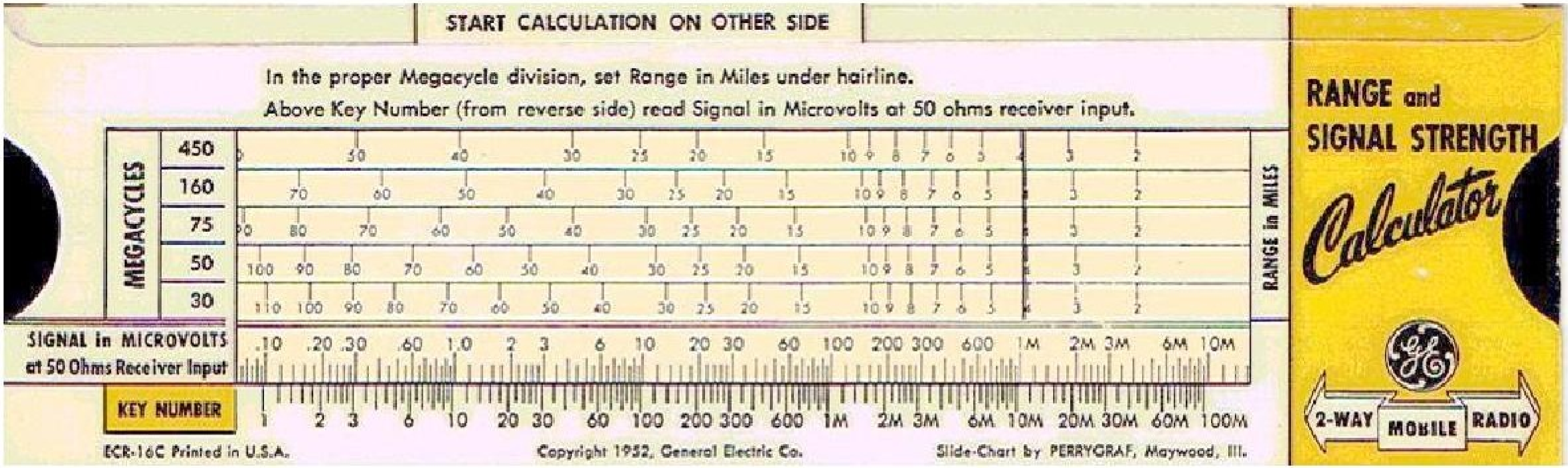
Best knowledge is that Dick Gifford created this calculator





The General Electric Range and Signal Strength Calculator for Two-Way Radio

Radio propagation is subject to so many variables that it is not possible to define precisely the geographical area or range that will be covered by a given installation. Some of these variable factors are: The distance of transmission, the frequency, the time of day, the season, the year, meteorological factors, the location of the transmission path with respect to land and sea and aurora zone, the amount of penetration into various layers of the upper atmosphere, the conductivity and dialectic constant of the ground and air and the effects occurring on the sun and stars, etc. Nevertheless, our present know-ledge of the behavior of the various frequency bands makes it possible for us to make reasonably good estimates of what can be expected.

The G.E, range and signal strength calculator was designed by our Engineering Department to deal specifically with the frequency bands employed in the mobile services. It is based on the nomographs contained in Kenneth Bullington's paper, '"Radio Propagation at Frequencies Above 30 MC's', which was published in the IRE proceedings of October,1947. This "slide rule" is very useful to anyone desiring to estimate the communication range of a given land-mobile system. The steps to be taken in solving a particular problem are all explained on the calculator itself. To illustrate the technique let us solve a few problems.

Suppose we wish to know over how many miles we could communicate between a 50-watt land-station and a 50-watt mobile unit, operating in the 30MC band, with a 150 ft. station antenna. We will assume that we wish to deliver a 1 microvolt signal to the distant vehicle.

In the 30 MC band a mobile antenna is considered to be 20 ft, in height as explained on the calculator; therefore, we line up the two antenna heights of 150 ft, and 20 ft. Since we are dealing with 50-watt transmitters, there is no DB correction factor. Our "key number"then is read as 3M (three thousand). Note that this is the product of the two antenna heights (20 x 150 = 3000), We will assume that we have no antenna gain or transmission line loss. However, if the trans-mission line loss was 2 DB, for example, the "key number" would then become 2400,

Turning over the calculator, we line up 1 microvolt with the "key number' 3M. Observing the hair line on the 30 MC scale, we find that the range in miles for the system in question is 48. It will be found that this range checks very well with practical operating experience in the field.

As another example, let us determine how many microvolts could be delivered by a 50-watt mobile transmitter over a distance of forty miles to the receiver of another mobile operating in the 30 MC band.

We first line up the hairline with 40 miles on the 30 MC 'range in miles" scale; with two mobile units our antenna heights will be 20 ft. and 20 ft., therefore, our "key number" must be 20 x 20, or 400, We can readily calculate this without referring to the front side of the calculator. Lining up the 'key number', 400, with the signal-in-microvolts scale, we find our answer to be 0.22 microvolts,

If we wanted to increase this signal strength to 1 microvolt, we find that our mileage range would be reduced to 23 miles.

For a third example, let us determine over how many miles we could expect to communicate between two mobile units operating in the160 MC band if we wish to deliver a 1 microvolt signal to the receiver. Following the instructions printed on the calculator, we see that mobile units operating above 150 MC's are considered to have an antenna height of 6 ft., therefore our key number becomes 6 x 6, or 36. Turning to the reverse side of the slide rule, and lining up the "key number",36, with one microvolt, we find a range of 7 1/2 miles showing on the 160MC scale. Checking the 450 MC band with the same set of conditions, we find that the range has reduced to 7 miles.

The execution of these examples is fairly obvious, but, what about cases that are '"off-scale'"? Suppose we have a 1000 ft, antenna tower at each end of a 150 MC 70 mile point-to-point circuit. Assume that we have 250 watt transmitters at each end with directional antennas of 5 DB gain each, and transmission line loss of 3 DB each. How many microvolts would be delivered to the distant receiver? The key number is 1,000 x1,000 or 1,000,000, which is beyond the range of the scales. However, we can interpolate by reducing it by a factor of, say 10, provided that we raise the signal in microvolts by the same factor. Lining up the hair-line on the 160 MC scale with 70 miles, we find a signal of 1.4 micro-volts adjacent to the "key number" of 100,000; raising by a factor of10, the number of microvolts becomes 14 microvolts. Now, we must take the other factors into account

|250 watt transmitter	+ 7 Db
Antenna gain, 5 DB + 5 DB	10 Db
Total gain	<u>17 Db</u>
<u>Less</u> transmission line loss of 3DB + 3DB	<u>6 DB</u>
Net gain	11 DB

This means that our received signal will be 11 DB greater than 14 microvolts., Turning to the front side of the calculator, we line up the "key number', 14, (representing 14 microvolts, or 0 DB). Counting to the left, 11 DB, we find the "key number", 50, which, in terms of microvolts, will be 50 microvolts. This would be a very good point-to-point circuit. Actually, the transmitter power could be reduced to 50watts. This would reduce the 11 DB net gain to 4 DB net gain, and the signal would be 21 microvolts.,

The G.E. range and signal strength calculator is also very useful in determining voltage or power ratios in terms of decibels or vice versa. Referring to the + and - DB scales, note that the "key number"scale shows voltage ratios i.e., lining up "key number" 1 with O DB,we see that "key number" 2 is 6 DB, and "key number' 10 is 20 DB. The total DB spread showing on the scale is approximately 40 DB, and lining up "key number" 1 at -20 DB, the + 20 DB point on the scale shows a voltage ratio of 100, which is true. A voltage ratio of 100 is40 DB. These scales can be used to show power ratios also by dividing the number of DB by 2, For example, lining up O DB and "key number" 1,number 10 lines up with 20 DB, which divided by two is 10 DB, and a power ratio of 10 is 10 DB,

Another way to convert voltage ratios to power ratios; simply square the "key number', i.e,, 10 squared = 100, and a power ratio of 100 is 20 DB.

The maximum number of DB covered by the slide rule is 40 DB,However, we can handle still larger ratios by very simple interpolation. Suppose, for example, we wanted to determine the voltage ratio represented by 76 DB,

First of all,we should memorize the fact that voltage(and current)ratios progress in 20DB steps for every multiple of ten. To wit :10X = 20 DB 100X=40 DB 1000X = 60 DB 10,000X = 80 DB 100, 000X = 100 DB

One should also memorize the fact that power ratios progress in 10DB steps for every multiple of 10

.For example-10X = 10 DB 100X = 20 DB 1000X = 30 DB 10,000X = 40 DB 100, 000X = 50 DB

Now to get back to the problem of the voltage ratio represented by 76 DB,we know that 60DB is a ratio1000 times. According to our slide rule a ratio of 16 DB is 6,So to obtain the 76 DB ratio, we must multiply1000 x 6 which is,of course, 6000. Our answer then is that a voltage ratio of 6000 is 76 DB.

It is interesting to note that, within the limiting heights given on the calculator envelope, the number of microvolts delivered to a receiver is directly proportional to the antenna height. A 200-watt transmitter feeding a 100-ft. antenna would equal a 50-watt transmitter feeding a 200-ft antenna.

The "key number" scales take into account the "free space'" loss that occurs in radio transmission plus the additional loss due to the refraction of the radio wave around the earth's curvature beyond the horizon. This explains the need for the limiting height limitation. If antenna heights are greater than indicated, the de-fraction loss is obviously reduced, and the results shown by the calculator are pessimistic by two or more DB.

The calculator is designed to show propagation over smooth earth. Although, from a practical standpoint, it is also quite applicable to transmission path over gently rolling country. It does not, however,take into account shadow losses, due to large hills and mountains.

In using the signal strength calculator, bear in mind that the signal strength required to produce a readable signal depends,not only on the sensitivity of the receiver, but also on the electrical noise level prevailing at the receiving location. When a signal is coupled directly into a receiver from a signal generator,the signal competes only with the internal noise generated in the front end of the receiver itself, and a signal as low as 0.3 microvolts may quiet the receiver noise output by 20DB. However, when the receiver is connected to an antenna, a second source of noise is introduced and somewhat greater signal strength is required to give the same degree of readability even when the receiving station is remote from sources of electrical disturbances. In those instances where the antenna is near sources of electrical interference, such as power lines, automobile ignition systems, etc.,the radio signal must override still more noise, and its required strength is usually several times as specified in the receiver sensitivity measurements.

For this reason,it is very desirable to measure the noise level at a proposed station location prior to the actual selection of the location. Listed below is a summary showing the approximate value of signal strength that are normally required to produce a readable signal at various types of receiving location. These approximations are useful for planning purposes, but they do not take the place of an actual noise level measurement which should be made whenever possible in laying out a communication system,

RECEIVING CONDITIONS (25-50 MC) APPROXIMATE REQUIRED SIGNAL STRENGTH

At rural locations; several miles from houses, high voltage lines or main high-ways -----> 1.0 microvolt

Suburban areas; small towns away from heavy industrial activities; well suppressed vehicles operating on lightly traveled highways -----> 1.5 microvolts

Moderately industrialized areas; 1/4 mile from heavily traveled highways or high voltage lines; poorly suppressed vehicles; drilling rig installations with utility plant running.-----> 2.0 microvolts

Adjacent to high voltage lines or heavily traveled highways; atop downtown building in small cities. -----> 3.0 microvolts

In the downtown areas of large 5.metropolitan centers such as Houston, Dallas, etc. small towns -----> 5 microvolts to 10 microvolts

J, A. McCormick Radio Communication Equipment Section – May 1962

The Range and Signal Strength Calculator is available from Service Parts. Order #ECR-16C, They sell for 28¢ each.