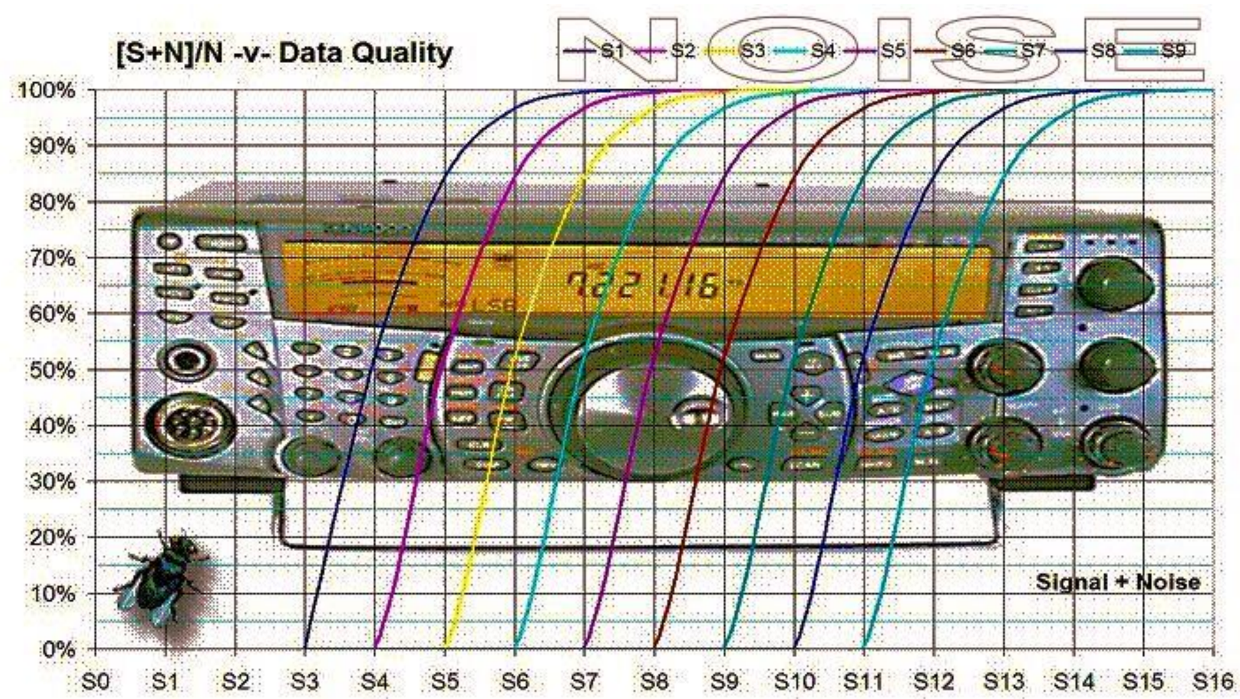
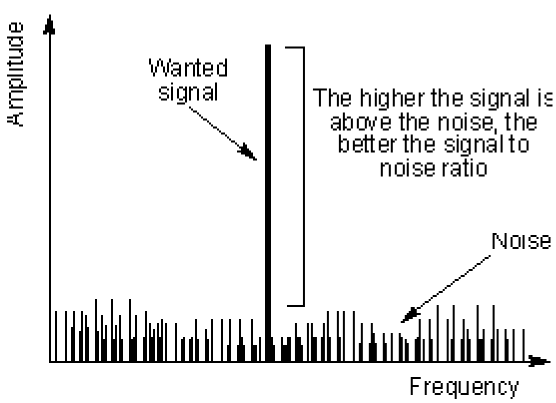
Seeking SNR

This investigation began months ago when Gary G7SLL shared an intriguing picture with me. It is a representation of the quality of an SSTV image, as a function of the received signal (specifically, signal (S) plus noise (N)) relative to the noise level (N) at the time of transmission.



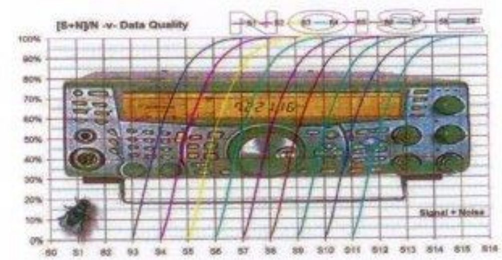
The aim is to maximize the [S+N]/N, or more precisely, the SNR ratio to enhance the quality of the SSTV image received. The greater the received signal is above the noise floor, the higher the quality the picture.



As I discuss my investigative journey, it would be helpful for the reader to print out the copy of my Excel document, as seen on the next page. Also, one can use the Seeking_SNR.sxls spreadsheet to examine the interactive features. Please note that these are all calibrated against my Kenwood TS-590S transceiver and its S9 signal adjustment for this rig as given by its S-meter.

Kenwood TS-590S transceiver; Force 12 C-3 antenna; antenna tuner disconnected
AGC off, RX preamplifier off, DSP filter 200 Hz/2800 Hz, USB @ 14.230 MHz
ACC2 Menu #67 set for 5 & RF gain set for 6
*Measure Soundcard Oscillator mV for 4 minutes and average

Kenwood TS-590S	Menu 67 Setting	RF Gain	Audio cable	Antenna	RX signal	mV Reading	Comment
Off			Shorted			15.07 uV*	
Off			Open			19.58 uV*	
Off			Connected			0.2*	
On	5	6	Connected	Dummy		0.56*	2.76 mV with menu 67 @ 4 & RF 10
On	5	6	Connected	Force 12	Negligible	1.22*	11.01 mV & menu 67 @ 5 & RF gain 10
On	5	9	Connected	RF Generator	S9 & AGC	66.6	AGC on & calibrate RF generator for S9
On	5	6	Connected	RF Generator	S9	183.5	AGC off with RF generator setting for S9
						8.8	dB gain by turning AGC off, ie, 183.5 vs. 66.6 mV

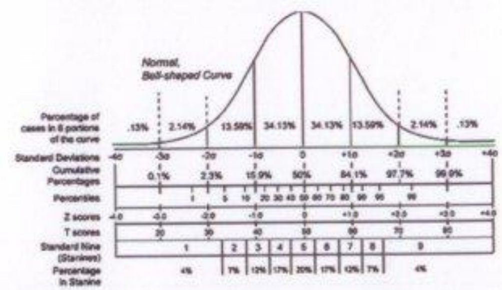


Imputed S-unit scale
using 183.5 mV for S9 and 6 dB attenuation per S-unit:

	S-unit	mV Value	
mV to S-unit converter	8.0	94.6	
Noise	2.0	1.5	
(S+N)/N dB = Sig	36.00		
SNR dB	35.99		
$Q[E]_{Sig}$	99.5%	P5	Broadcast quality

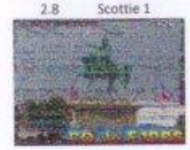
$Q[E]_{Sig} = erf(Sig/18)$

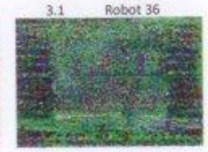
mV	S Unit	dB Over S2	$Q[E]_{Sig}$	P
580.3	10			
183.5	9	42	99.9%	P5
92.0	8	36	99.5%	P5
46.1	7	30	98.1%	P5
23.1	6	24	93.8%	P4
11.6	5	18	83.7%	P3
5.8	4	12	64.4%	P3
2.9	3	6	34.9%	P2
1.5	2	0	-1.6%	P0
0.7	1			



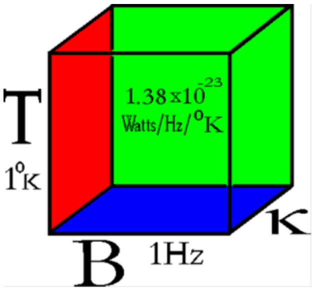
	Broadcast quality		Good, some noise		Usable, noisy		Barely use, noisy		Barely see text		Unusable	
P quality scale:	P5 >	97.7%	P4	84.1-97.7%	P3	50-84.1%	P2	15.9-50%	P1	2.3-15.9%	P0<	2.3%
Q[E] value: Sig mV =	79.43	99.4%	37.57	95.5%	5.04	56.6%	2.46	33.7%	4.01	8.8%	3.19	5.2%
Noise mV =	1.37		2.00		1.60		1.30		3.41		2.90	
Sig S-unit	7.8		6.7	Scottie 1	3.8	Martin 1	2.8	Scottie 1	3.5	Scottie 1	3.1	Robot 36

Empirical observations:



My first step was to understand **noise power** and the formula to express this quantity, κ x T x B. This exploration is documented in a separate article, Sky Noise, and I will not discuss it here. A visual depiction of noise power per unit is:



Before I could really dig in for a better understanding and measurement of SNR, I needed to improve my station. Gary Peach was very supportive and gave me excellent guidance. Here is a list of significant improvements I made, and they do provide remarkable results for better SSTV signal reception. I'll start with the receiver and describe my steps into my computer.

Before I could really dig in for a better understanding and measurement of SNR, I needed to improve my station. Gary Peach was very supportive and gave me excellent guidance. Here is a list of significant improvements I made, and they do provide remarkable results for better SSTV signal reception. I'll start with the receiver and describe my steps into my computer.

- I turned off the **Rx pre-amplifier**. That just amplifies the noise and for most HF frequencies it hinders reception more than it helps.
- I turned off the **AGC**. That makes an amazing difference. Signal levels increase and the dynamic range function of AGC no longer distorts the relative signal levels.
- I tapped the **line output** from my transceiver via the rear panel AGG2 connector, instead of from my headphone jack. I have better impedance matching with my soundcard, and a nice steady audio signal is delivered. I chose a menu #67 setting of 5.

- I reduced the **RF gain**. I experimented with a level which further minimized amplification of noise, yet would allow me to consistently receive weak and strong signals. I chose an RF gain level of 6.

I selected S6 by using the Soundcard Oscilloscope (discussed soon), first with the Kenwood receiver connected to a 50 ohm dummy load. I observed the mV reading. Then with the Force 12 Yagi connected, I adjusted the RF gain control for double the mV reading, or a 3 dB increase over the baseline measurement. This reduces the noise burden on the early stage transistors in my receiver, hence improving linearity and reducing compression at higher signal levels.

- I set the **DSP filter** to a range of 1000 Hz and 2400 Hz.

It is critical that noise power be reduced in order to enhance the SNR. I often copy SSTV signals. The sync tone is 1200 Hz and the image scan ranges from 1500 to 2300 Hz. Hence, a narrowed DSP filter setting of 1000 (low) to 2400 Hz (high) helps eliminate unnecessary reception bandwidth for SSTV and controls the amount of noise power received.

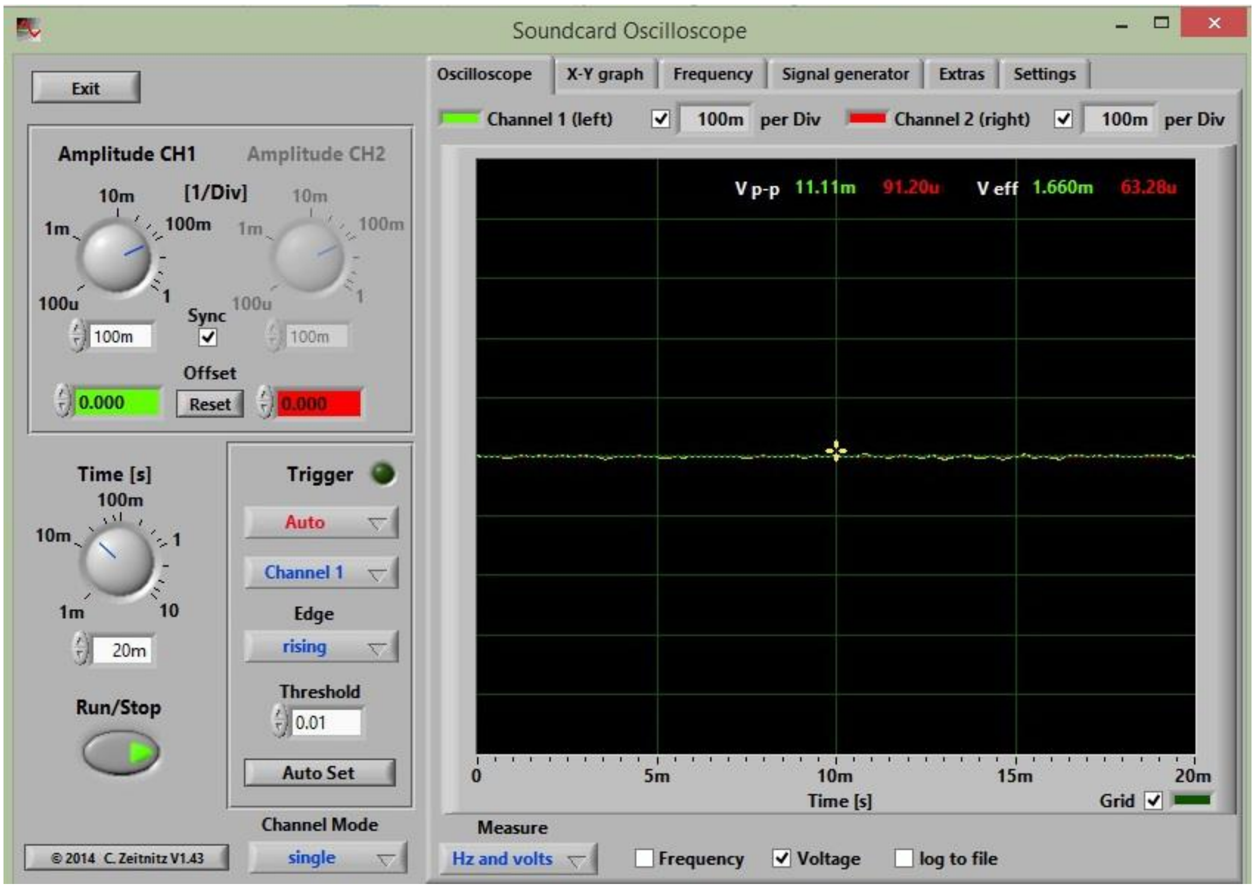
I have experimented with SSB signals and find that a DSP setting of 300 Hz (low) and 3400 Hz (high) enhances reception without letting in too much noise under normal conditions. While I can understand a ham who transmits SSB during an SSTV QSO with narrower DSP settings for SSTV, I will, at a minimum, adjust the lower passband setting to 300 Hz for better fidelity.

I installed two important items in my desktop computer. First deals with the **soundcard**.

- I purchased a Sound Blaster ZxR ultralow noise soundcard.
- I connected my rig output to the ZxR auxiliary input jack.
- Sampling is set for 24 bit, 96000 Hz.
- The volume is set to 100%.

Second, I installed the **Soundcard Oscilloscope**. This enables me to measure the audio voltage for noise and the received signal. Here is an example of how this is set up. I am only receiving background noise on 14.230 MHz.

This shows a current noise floor voltage as 1.660 mV RMS. When I adjusted settings, I regularly used the 'log to file' procedure. This allowed me to create csv files. I then converted them to Excel format and performed mathematical calculations for the time series of voltage data. This was relied upon for the measurements and calibrations which I will discuss next.



The upper left hand corner of the Seeking SNR document on page 2 shows the **results of adjusting**.

1. I first examined the voltage readings with the rig turned off and the connecting audio cable shorted, open and then connected to the ACC2 jack of the transceiver.
2. Next I turned on the rig and observed the noise generated with the Rx connected to a 50 ohm dummy load.

3. Then I connected to my Force 12 C-3 beam during a quiet period and noted a low 1.22 mV signal. (The above screen shot is somewhat higher at the moment. Without any man made QRM, I normally have a noise floor somewhere in this range.)
4. I used this information, plus observations of live ham signals, to determine useful settings for the RF gain and #67 menu for receiver line output.
5. Finally, I began the signal level calibration process using the rig's S9 as the industry standard for S9 is -73 dBm.

I used an RF signal generator for a frequency at 14.230 MHz. With the AGC turned on so that the S-meter would function, I carefully set the power output of the generator so as to produce an S9 signal reading on the S-meter. Then I turned off the AGC and noted the mV reading, ie, 183.5 mV. I repeated this process over and over, carefully watching both the frequency modulation (for stability and no drift) and the voltage readings, until I was satisfied with a **good estimate for S9 with AGC off**. The difference in reading with AGC on and off is 8.8 dB. This is a result of (1-Hs), where Hs is the receiver transfer function or 'AGC compression ratio.'

Armed with a voltage reading for S9, assuming an appropriate calibration of the Kenwood TS-590S receiver, I could now make a **theoretical calculation for all the lower S-unit levels**, using the standard spread of 6 dB per one S-unit.

This is noted in the middle table. For example, S7 is 46.1 mV, a common signal level for hams transmitting SSTV pictures. And a weaker SSTV signal might be around S4 or 5.8 mV.

To the left is a **calculator**. One can input the received [S+N] mV value, eg, 94.6, and the received noise level [N], eg, 1.5 mV. This automatically calculates a series of information:

- Received S-unit = S8.0
- Noise S-unit = S2.0
- [S+N]/N = Sig = 36.00 dB
- SNR = 35.99 dB
- Q[E]Sig = 99.5%

I spent days and easily over 20 hours trying to figure out a way to calculate the picture quality. I eventually ended up using Gary's graph and an accompanying table that he had provided months prior. I also noticed that his curves approximated the right side, or one-half of the erf error function.

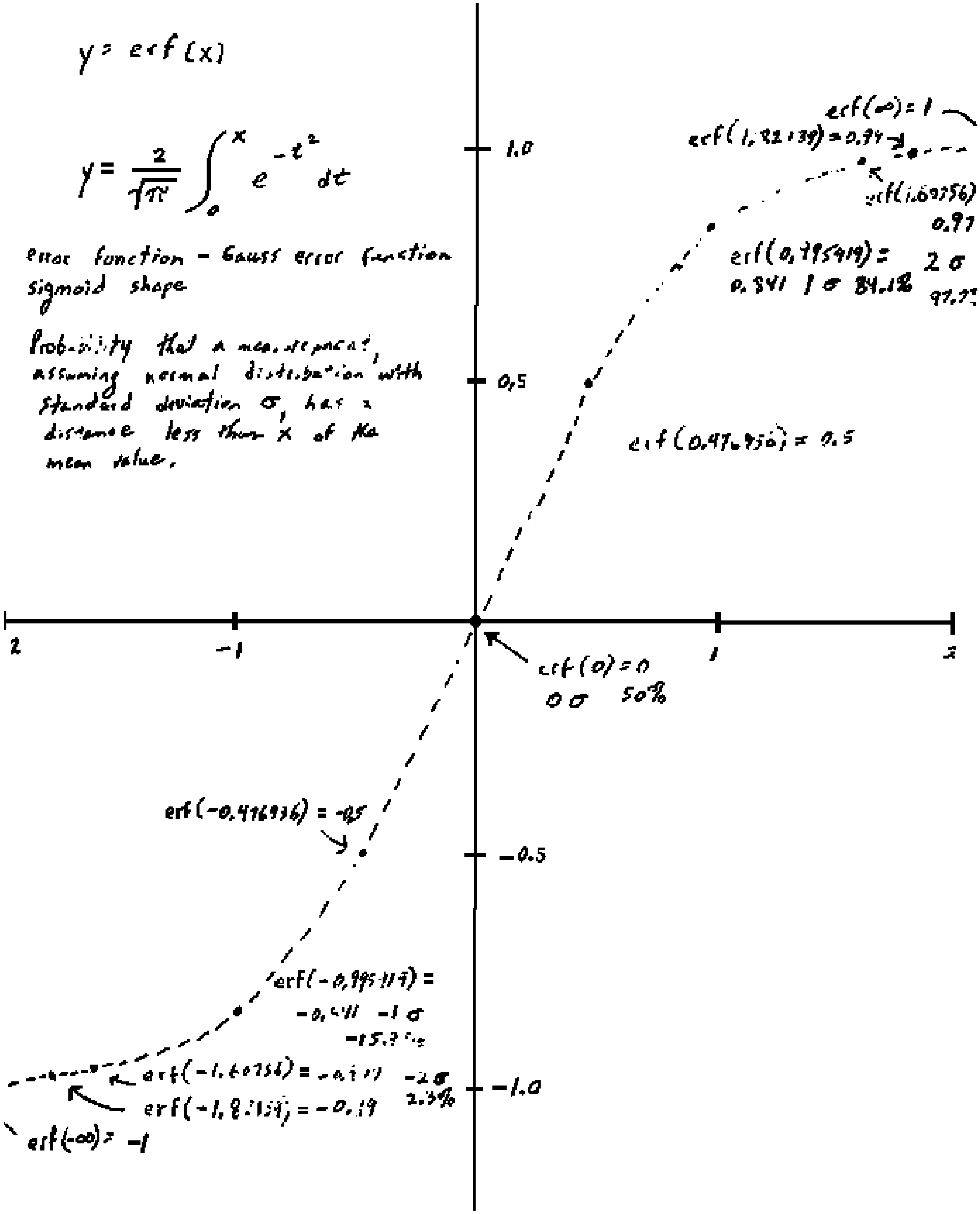
I had spent time graphing erf for many important x,y points from x = - ∞ to + ∞. As I noticed on the following page, the error function might be used to express **quality, Q[E]Sig**, if I assumed 0% quality occurred when the signal was exactly at the Threshold noise level as it crosses the x,y erf axis at 0,0.

$y = \mathrm{erf}(x)$

$$y = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2}\, dt$$

error function - Gauss error function
sigmoid shape

Probability that a measurement, assuming normal distribution with standard deviation σ, has a distance less than x of the mean value.

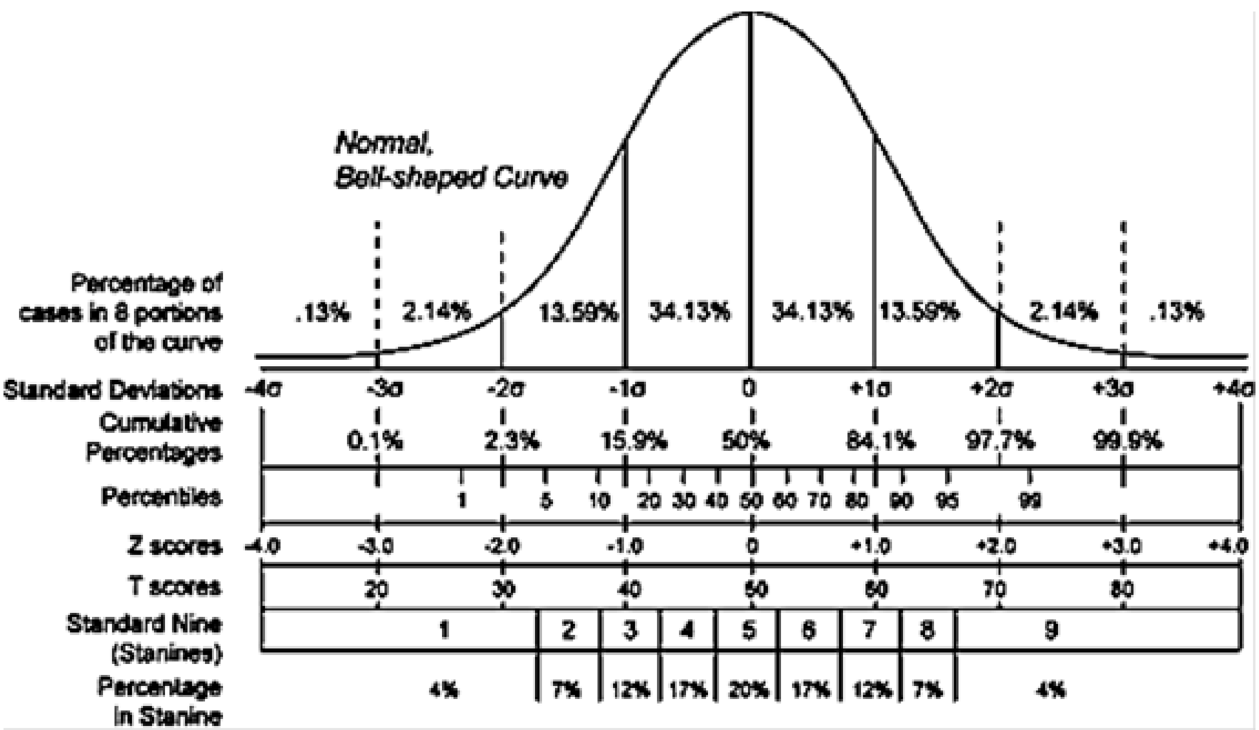


The problem then was to figure out how to develop a formula to match Gary's chart. His given values from an August 2, 2014 document were:

[S+N] – N	**Percentage**
12 dB	0.3%
18 dB	52.4%
24 dB	84.5%
30 dB	96.7%
36 dB	99.5%
42 dB	100.0%

I failed to precisely fit <u>all</u> percentages to the right side of the erf curve, but then I noticed that I could match the 99.5% value = erf(2). Gary furnished a 36 dB difference in [S+N] to N value, so that fit nicely. Hence, I used the equation Q[E]Sig = erf(Sig/18)

With a reasonable formula for Q[E], I could then proceed to group percentages into a measurement system used by video broadcast engineers, a **P scale** from P5 (broadcast quality) to P0 (unusable). But how? I turned back to the probability chart and used some key standard deviation points to demark intervals.



I propose the following approach for relating broader ranges of Q[E] values to P signal levels:

Q[E] Range	Standard Deviation	P Signal	Verbal description of image
100 – 97.7%	Greater than 2σ	5	Broadcast quality
97.7 - 84.1%	1σ to 2σ	4	Good, some noise
84.1 – 50%	0 to 1σ	3	Usable, noisy
50 – 15.9%	-1σ to 0	2*	Barely use, noisy
15.9 – 2.3%	-2σ to -1σ	1*	Barely see text
2.3 to 0%	Less than -2σ	0*	Unusable

Lastly, I made **empirical observations** of received SSTV signals. I conducted time series mV studies with the Soundcard Oscilloscope to determine mean [S+N] and N values. The images correlate well with the Q[E] values and P descriptions.

*As can been seen from the empirical observations, signals in the P2 to P0 range are all barely usable, if at all. I have categorized these final three P levels for completeness of presentation, ie, there are modest differences in SNR, visual intelligence and consistency of standard deviation distribution in 1σ spreads.

In practice, there are essentially four categories of signal quality:

- P5: broadcast quality
- P4: good, some noise
- P3: usable, noisy
- Other: poor reception

Larry WB9KMW @ WB9KMW.com