A Novel Perspective of Amateur Radio Contesting

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1. The idea

The contest community is a unique group of individuals who are always seeking innovative ways to draw others, young and old, into the broader realm of the worldwide amateur radio community. Of course, in the back of their minds is a secret desire to encourage old members as well as newcomers to participant in their unusual past time -- CONTESTING! Furthermore, their experiences with clear, concise and rapid message exchanges made them ideal candidates to quickly embrace Internet techniques for exchanging their views and information between contest sessions. Recently there have been indications that some of the major community magazines want to move contest results from their printed pages to the web. Needless to say this has produced a flurry of emails debating the pros and cons of such a move. Is this a good thing or bad thing? Perhaps it depends on the opportunities the transition to the web might present.

In this article I would like to present another way of looking at 'the sport of contesting'. I will suggest that leaving much of the descriptive contest material on the printed page and moving the contest results and other data to the web might open some doors for us. It may even help us make unusual contributions, not only to our own community, but also perhaps to the broader scientific community. If you have a little time, I would like to invite you to sit back, relax and travel with me on a journey through a novel perspective of amateur radio contesting.

Let me begin by posing a hypothetical situation. Assume we used a set of contest logs to create a list of confirmed contacts. Furthermore, assume that each entry in the list contains the time of the contact, the band on which it occurred and the maidenhead locators of communicating stations. Now assume that we use this list to graphically display how the nature of the contest system evolved over time. For example, for each minute of the contest we could draw lines on a world map connecting pairs of communicating stations. If we display the series of maps in sequence it would be similar to a motion picture of the contest system.

What do you think we would see? Would we see a contest system that was composed of a random collection of point-to-point communications, or would we see a contest system that had dynamic structure and form? In fact, we might ask ourselves what techniques could we use to determine if the character of the contest system was merely composed of random patterns or if it had inherent order?

To the best of my knowledge, no one has done this sort of thing. Maybe, before we engage ourselves in such a complicated and time-consuming activity, we might look for clues to see if the effort might be worthwhile. What data could we use to look for these clues? Perhaps we might get some clues if we explored contest results derived from individual contest logs, that summarizes the total number of contacts, multipliers and the final score for each participant - the sort of information that is currently published in magazines.

The focus of this article is to show that by using the summary results from a variety of contests and some new scientific techniques, we can uncover powerful indications that a contest system has a unique character that emerges over time. Furthermore, its character is formed by the collective activities of individual participants combined with the forces of nature that influence radio communication. In fact, I will show that some of its character can be measured and it can be used to give us deeper insight into the general nature of contesting. More importantly, this information can help individuals put their contest performance into a new and wider perspective. This article will conclude with the suggestion that perhaps we could use our contest logs to assist us to better understand our own contest activities, improve our skills, and perhaps even make a novel contribution to the scientific community. Let me begin with a brief discussion about the nature of contests, contest stations and contestants.

2. The contest, the station and the contestant

The goal of most contests is relatively straightforward. Essentially the rules encourage participants to achieve as high a score as possible by working as many stations and multipliers as possible on one or more bands. The overall victory goes to those stations with the highest score in each contest category and/or region.

It takes a lot of planning and work to build a competitive contest station. Many hours are spent designing, constructing and testing the station and antenna system. However, given a station's surrounding environment and by using best practice engineering principles, an optimum technical solution can be found for nearly every conceivable situation. In other words, while the building of a contest station requires a great deal of ingenuity and hard work, today in general, the result is predictable and reproducible.

Interwoven with the technical design and construction are personal development activities that hone individual skills and strategies. CW operators may challenge their speed and accuracy on the air or by using a contest simulator package. SSB operators may strive to find the ideal vox and audio compression settings and they may participate in traffic nets both for enjoyment and to sharpen their messaging skills. Many hours may be spent configuring the contest logging software, preparing propagation charts and building databases of useful information. Consciously and subconsciously, each operator creates a personal strategy to optimize his contest performance within the confines of his financial, geographical, physical and technical resource limitations.

Once a contest has begun, the participants have entered a complex system, and they intuitively know that its unique character will slowly emerge over the contest period. Also they know that its character will be formed by a combination of many predictable and unpredictable factors. For example, while HF propagation may be partially determined by the predictable rising and setting of the sun, the nearly unpredictable solar winds may blow foul or fair; or the next door neighbor may decide to do some arc welding creating rfi; or mother nature may suddenly illuminate the sky with lightning at moment of a prearranged sked with a rare multiplier. On the other hand there are interesting instances when a contestant works an unexpected and rare multiplier off the back of a high performance yagi and yet for some reason encounters difficulty working a garden variety multiplier in the direction in which the antenna is pointed. A contest seems to hover on the edge of order and disorder. Yet out of its turbulent, chaotic nature each contest evolves a character that provides the humorous and sometimes tragic content of post-contest emails and articles.

3. The anatomy of a contest

Exactly what is amateur radio contesting? Using a series of observations I hope to convince you that merely by participating in a contest you are helping to organize or create a contest’s distinctive character. In fact, I hope to illustrate that, in concert with mother nature, the collective activities of the contest participants produces a nonlinear, dynamic contest system and some of its unique characteristics can be measured. This involves using a few graphs derived from contest results and an equation similar to Ohm’s Law to illustrate my point.

Let me begin with a rather trivial observation. In a contest, a multiplier is just a special kind of contact. In other words, contacts and multipliers are related and working a new multiplier usually results in getting credit for the contact[2] too. Sometimes a contact can even count as two multipliers. For example, the first contact in the CQ WW contest can give you 1, 2 or 3 contact points, depending on who you work, plus a country and a zone multiplier.

Let me remind you what is meant by the term *nonlinear.* A value is *linearly* related to another value if the first value is *proportional* to the second value. In other words, if you multiply the first value by a constant then the second value will increase by the same constant amount. For example, in Ohm’s Law the voltage (E) is related to the current (I) and the resistance (R) by the relationship $E = IR$. If R is held constant and I is doubled or if I is held constant and R is doubled then E will double too. In other words, the voltage is linearly related to the current or the resistance if the other remains constant. On the other hand, power (P), is related to the current and voltage by the relationship $P = I^2R$. We can see that P is linearly related to R

when *I* is held constant. However, *P* is *nonlinearly* related to *I* when *R* is held constant. This is illustrated by the fact for constant *R*, if I is doubled, the power increases by a factor of four times. This is a *non-proportional* increase.

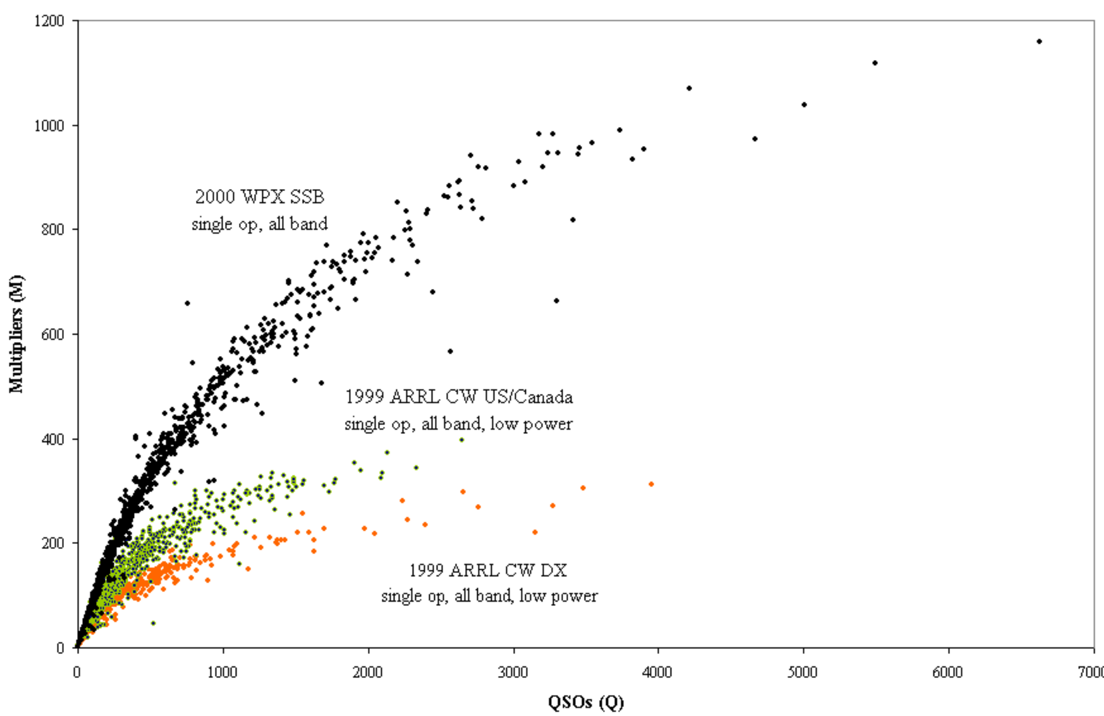
Now let us look at how contests are scored. Assume for the moment that each contact is worth *c* points and each multiplier is worth one point. A contestant's total score[3] is usually determined by multiplying the value of a contact (c), by the number of contacts or QSOs (Q) and the total number of multipliers (*M*) i.e. $S = cQM$. Theoretically speaking, using this scoring system the minimum attainable score would occur in a contest that has no multipliers i.e. S = cQ. The maximum attainable score would occur in a contest where each contact produced a new multiplier (i.e. $M = Q$) and therefore $S = cQ^2$. In this theoretical case it is easy to see that the score would be nonlinearly related to the number of contacts and multipliers since if the number of contacts were doubled, the score would increase by fourfold.

This particular kind of nonlinear relationship is called a *power law*[4] because the amount by which S increases is determined by the *power of* Q, which is in this instance equal to 2. In a typical contest each contact does not produce a multiplier. However, we do know from my trivial observation that there must be some sort of a relationship between *M* and *Q*. Perhaps if we can demonstrate that *M* and *Q* are related in a nonlinear manner, then we can also claim that the score has a nonlinear relationship with the product of *M* and *Q*.

Intuitively we understand that as we make more contacts it becomes more difficult to work a new multiplier. This is due to the fact that while there may be thousands of stations participating in each contest by comparison there are fewer multipliers. Another way of looking at it is that there are approximately 350 DX CC countries, 40 CQ zones and 75 ITU zones. There are a varying number of contestants in each multiplier region. Also, it is easier to work many contestants in a highly populated multiplier region than to work the sole contestant in a rare multiplier region.

Actual data from the 2000 WPX phone and ARRL CW contests is presented in Figure 1 and it supports this idea. In this graph the number of multipliers and number of contacts is plotted for each contest participant.

Figure 1 - Multipliers and QSOs



In both instances we see that the number of multipliers increases in a nonlinear manner with the number of contacts[5]. We know that it is nonlinear because the number of multipliers worked in a contest decreases as the number of contacts increases. In other words the relationship between the number of contacts and the number of multipliers worked is not proportional. I have examined the relationship between M and Q for all modes and classes in the CQ WW, ARRL, WPX and RAC contests and in every case the relationship was nonlinear.

Over the past few decades researchers have shown that nonlinear characteristics are frequently associated with dynamic systems[6]. Simply stated a dynamic system is a system that changes with time. For example, a river with turbulent water flowing along its banks and the continuously changing rf reflective properties of the ionosphere are dynamic systems. One of the reasons a contest is a dynamic system is the changing reflective property of the ionosphere during the contest. This strongly influences the nature of a contest.

If we examined the contest logs, perhaps an example of another nonlinear property that might emerge from the dynamics of a contest is the frequency distribution of time intervals between successive contacts. We have all experienced clusters of contact activity and inactivity during a contest. In fact, even within each cluster of activity there are smaller clusters of activity and inactivity and so on. This is analogous to noise bursts that have been shown to have a power law or nonlinear time interval distributions[7]; that is, there is a high frequency of short intervals and relatively low frequency of longer intervals. This characteristic arises partly because at any given time certain regions of the world have good propagation into densely populated areas, while other regions do not, and the propagation also changes with time. Participants are always leaving and entering the contest, as well, they are changing frequencies and bands. This also contributes to the dynamic nature of a contest system. We are beginning to see hints that a contest might be a nonlinear, dynamic system. What can contestants do to maximize their score in a contest?

4. Maximizing the score

Once a contest begins some things are under a contestant's control (e.g. operating time, band, transmitter frequency, and antenna direction) while other things are completely determined by natural processes (e.g. propagation conditions) and the contest system as a whole (e.g. number of contestants on each band). Once the contest begins there is relatively little a contestant can do to change his setup, skills, and location. In fact, the potential maximum number of contacts and multipliers a contestant can work is determined by the contest system and not by the contestant. The contestant can only strive to work as many of the potential contacts and multipliers as possible on each band.

One factor that a contestant has some control over before a contest begins is the effective radiated power (ERP) on each band. The ERP on a band can be maximized through the use of a linear amplifier, a high gain antenna and a low loss feed system. We can see the effect of power on number of contacts in Table 1.

Table 1 gives the highest number of contacts that were made by participants in the single operator, all band categories for each mode and power class for a variety of contests. For each contest mode and category the ratio between the highest numbers of contacts made in a given power class to the highest number made in the lowest power class is recorded in the last column. In every instance it can be seen that as the power increases the number of contacts increases. This should leave little doubt in anyone's mind that maximizing ERP as part of the pre-contest strategy is a significant contributing factor to maximizing the number of contacts.

Table 1 - Relationship between power and number of contacts

Contest	Mode	Category	Class	Contacts	Ratio
ARRL 1999	CW	US-Canada	A	292	1.00
			B	2,643	9.05
			C	4,318	14.79
		DX	A	986	1.00
			B	3,275	3.32
			C	5,199	5.27
	SSB	US-Canada	A	1,234	1.00
			B	1,559	1.26
			C	4,588	3.72
		DX	A	781	1.00
			B	4,746	6.08
			C	7,408	9.49
WPX 2000	CW		QRP	1,093	1.00
			Triband - LP	1,934	1.77
			Triband - HP	3,648	3.34
			SO	4,517	4.13
	SSB		QRP	1,119	1.00
			Triband - LP	2,571	2.30
			Triband - HP	2,633	2.35
			SO	6,623	5.92
RAC 1999	CW & SSB		LP	1,215	1.00
			HP	1,435	1.18
CQ WW 1999	CW		QRP	3,277	1.00
			LP	4,894	1.49
			HP	7,001	2.14
	SSB		QRP	1,942	1.00
			LP	3,994	2.06
			HP	10,253	5.28

An effective contest strategy includes doing such things as planning band changes and pointing rotatable antennas in the direction that will maximize the likelihood of working multipliers or increase the contact rate. This means that a contestant has to continuously follow the changing propagation conditions and the position of the sun as the earth spins on its axis.

Low power contestants have to determine how much time to spend in CQ mode and how much to spend in search and pounce (S&P) mode. If too much time is spent in CQ mode then some multipliers may be missed. On the other hand, if too much time is spent in S&P mode then the contact rate will be lower. A contestant located in a rare multiplier region may have to decide when to leave the CQ mode and go to S&P mode in order to work other contestants in rare multiplier areas. Needless to say the QRP contestant has to decide whether it is even worthwhile moving from the S&P mode to the CQ mode.

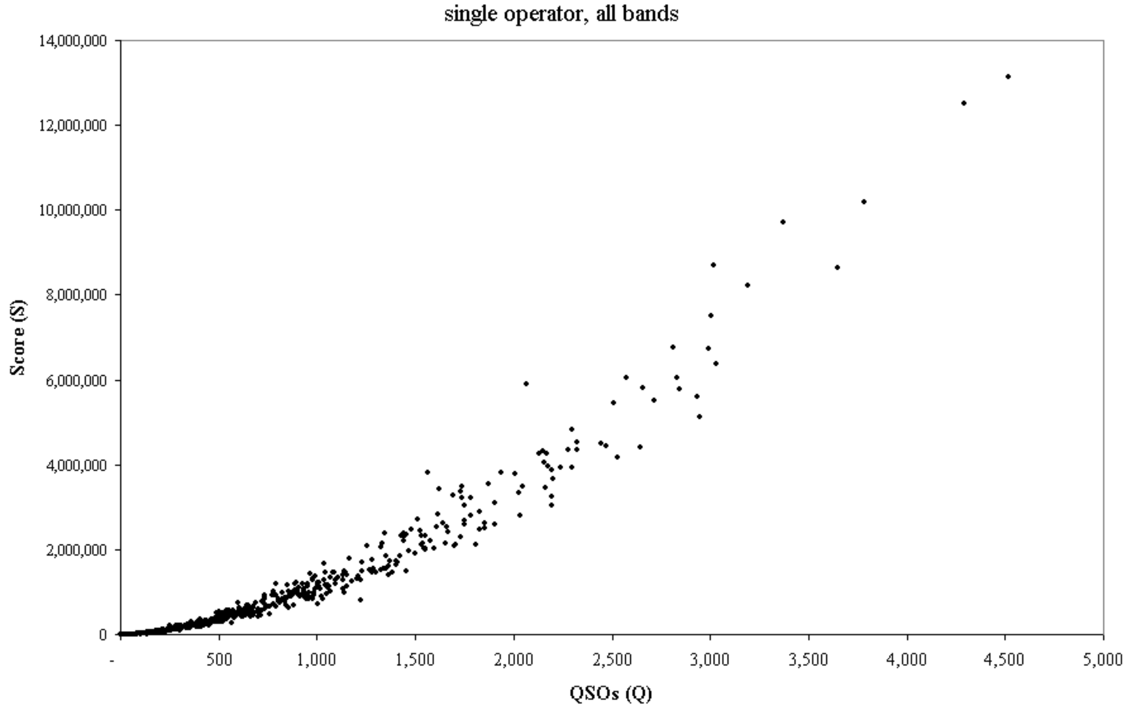
The process of optimizing a contest score involves continuously making decisions about when to change bands, frequencies, antenna direction, modes, take rest breaks and so on. In fact, an optimum strategy is a dynamic strategy that strives to maximize the number of contacts and multipliers worked on each band based on experience, planning and knowledge of the current propagation conditions. This is another reason that we can assert that a contest is a dynamic system. Now let me see if I can find some empirical evidence to support the claim that a contest system is a nonlinear, dynamic system.

5. Scores and QSOs

The technique I am going to present is somewhat novel and based on experimental and theoretical research into nonlinear, dynamic physical and social systems. There has been an extensive amount of research done in this area and the notes at the end of the article provide some references to the literature on the topic. I will start by jumping into the deep end to let you see where I am going, and then I will backtrack and give more details.

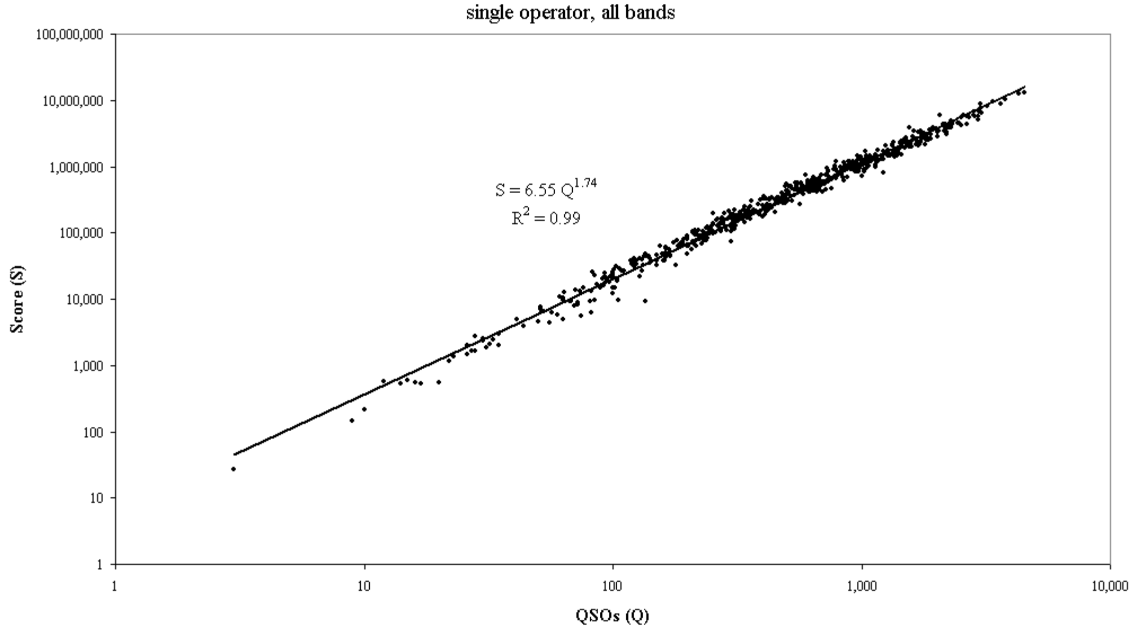
Figure 2a and 2b are plots of the score versus the number of contacts for single operator, all band 2000 WPX CW contestants whose results were reported to CQ magazine[8]. The only difference between the two plots is that Figure 2a is plotted on a linear scale and Figure 2b is plotted on a log-log scale. In addition, Figure 2b has a straight line drawn through the data points and the reason for this will be explained shortly.

Figure 2a - 2000 WPX CW Contest
single operator, all bands



In this contest participants entered logs containing between 3 and 4,517 contacts and had scores ranging between 27 and 13,140,000 points. As predicted earlier and is now apparent from Figure 2a, the relationship between the score and number of contacts is nonlinear. Now, if we plot the data from Figure 2a on a log-log scale as in Figure 2b we will see a rather strange fact. The points appear to fall along a straight line. This is a common occurrence when there is a power law relationship between two variables. Let me take a moment to explain why this occurs.

Figure 2b - 2000 WPX CW Contest
single operator, all bands



Recall that the contest with the highest possible score would be one in which each QSO is also a multiplier i.e. Q = M. The relationship between the score and the number of contacts is given by the equation

$$S = cQ^2 \qquad (1)$$

where c is a constant representing the number of points per contact. Now, let me generalize this equation from one where the score is strictly related to the number of contacts by the power of 2, to one in which the score is related to the number of contacts by any power n. I do this by writing equation (1) as follows

$$S = cQ^n \qquad (2)$$

where n is any real number[9]. Note if $n = 2$ we get equation (1).

Now, if we take the logarithm of each side of equation (2) we get

$$\log S = \log c + n \log Q \qquad (3)$$

Since the logarithm of a constant (i.e. log c) is just another constant we can re-write this equation as

$$\log S = k + n \log Q \qquad (4)$$

where $k = \log c$. If you think back to your high school algebra you will recall that the equation for a straight line is given by

$$y = a + bx \qquad (5)$$

where a is the y-intercept and b is the slope of the line. A close examination of equations (4) and (5) reveals that they have the same general form where y equivalent to log S, x equivalent to log Q, a equivalent to k and b equivalent to n. In fact, any power law plotted on a log-log graph will give a straight line. The slope of the line will be equal to the exponent of the power law.

In summary, if two variables are plotted on a log-log graph and if the points fall on a straight line this indicates that there is nonlinear relationship between the variables and this relationship can be described by a power law equation with an exponent equal to the slope of the line.

The straight line drawn through the contest data points in Figure 2b was produced using a statistical technique[10] to calculate the slope and y-intercept of the power law equation that gave the best fit to the data.

For single operator, all band 2000 WPX CW contestants the power law is $S = 6.55\ Q^{1.75}$. There is another value given on the graph called the R-squared value or coefficient of determination[11]. Simply stated this value is a measure of how well the equation fits the data. If $R^2 = 1$ the fit is perfect and if $R^2 = 0$ there is no fit at all. In this case $R^2 = 0.99$ indicating that the equation fits the data very well. Now let us ask the question "What does this equation actually represent?"

First, I will give you a summary of what the power law equation represents and then I will give you the details. Simply stated given the *character of a contest system* and *any subset of competitors* in the system, the power law equation that best describes the relationship between the score and the number of contacts can be used to calculate the *average expected* score for a contestant given the *actual* number of contacts the contestant made. For example, in the 2000 WPX CW contest a single operator, all band contestant who made 500 contacts would be expected to have a score of 346,289 points (i.e. $S = 6.44\ 500^{1.75}$).

Some key phrases have been highlighted with italics. Let us stop and examine these phrases in a little more detail. In an earlier part of this article I described what I meant by the *character of a contest system* when I said:

> Once a contest has begun, the participants have entered a complex system, and they intuitively know that its unique character will slowly emerge over the contest period. Also they know that its character will be formed by a combination of many predictable and unpredictable factors.

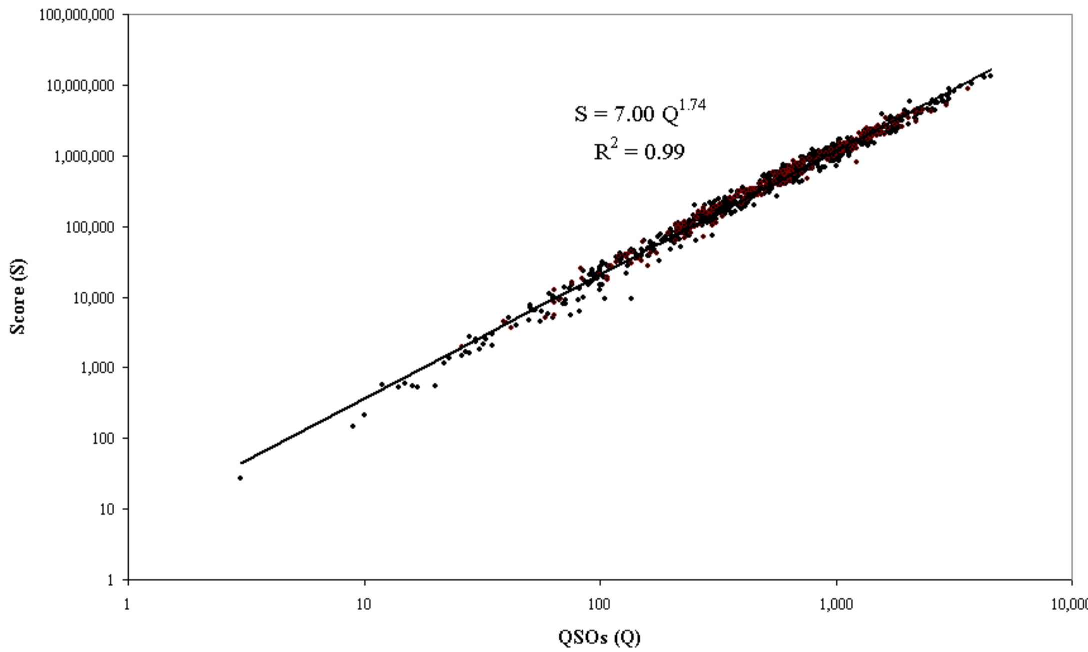
I demonstrated that many predictable and unpredictable factors such as the rising and setting of the sun, the rf reflective properties of the ionosphere, the number contestants, and so on can make an amateur radio contest a nonlinear, dynamic system. After the contest is over its character has completely emerged and it was defined by the interaction of all of the predictable and unpredictable factors contributed by nature and the contestants. Now select a *subset of competitors* (e.g. only contestants in the *single operator, all band* category) from the contest system (e.g. *2000 WPX CW contest*) and plot their scores against the number of contacts they made. The equation that best fits the data can be used to calculate an average *expected* score for any competitor in the subset of contestants, given the number of contacts the contestant made. It is also a measure of the character of the system. In other words, given the character of a particular contest system, a competitor with an actual score equal to the expected score is considered to have exhibited an *average* contest performance. A competitor with an actual score lower than the expected score is considered to have had a *below average* performance. Finally, a competitor with an actual score above the expected score is considered to have had an *above average* contest performance.

"So what! ", you may say, "The score always increases as the number of contacts increases." This is true but the score could have increased linearly or exponentially with the number of contacts. It may even have increased according to a complicated mathematical relationship with the number of contacts. However, since the score increased in a power law relationship with the number of contacts, and it is well known that a power laws is a characteristic signature of nonlinear dynamic systems, then we can be quite certain a contest system is a nonlinear dynamic system[12].

The exponent of a power law describing the relationship between the score and the number of contacts may change a little or a lot as the subset of competitors is changed[13]. Or in some instances the system may be divided into subsystems due to the rules of the contest. Let us explore this claim in more detail.

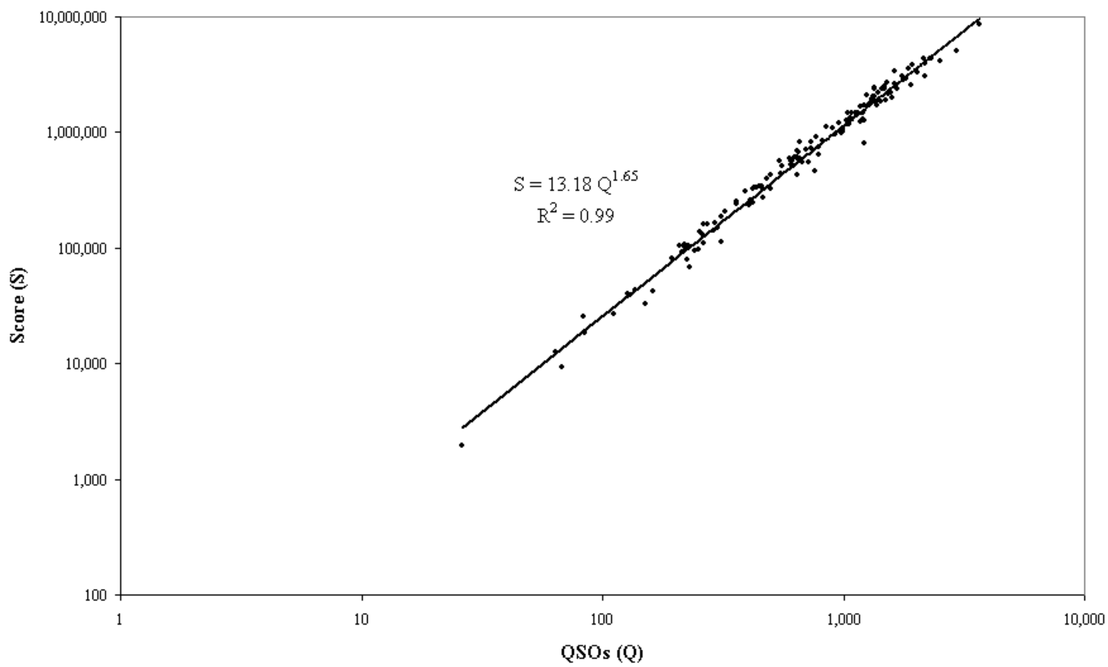
Figure 3 is a log-log plot of the 2000 WPX CW contest as seen in Figure 2b except that the subset of competitors has been expanded to include contestants in the high and low power tri-band and QRP categories.

Figure 3 - 2000 WPX CW Contest
single operator, tribander high & low power, QRP, all bands

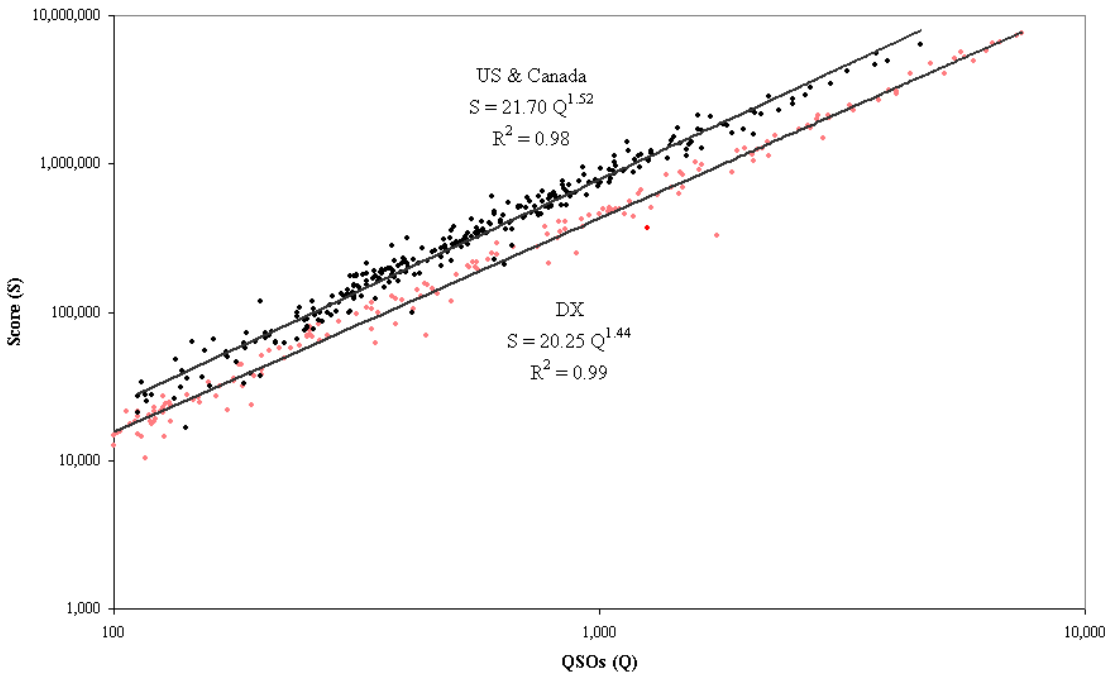


Notice that including these new categories produced no significant change in the exponent. Now, if we restrict the subset of competitors to the single operator, low and high power tri-band contestants as shown in Figure 4, we see the exponent decreased slightly to 1.65.

Figure 4 - 2000 WPX CW Contest
tribander low and high power, all bands



A more dramatic difference can be seen when we look at the results for the 1999 ARRL SSB contest. Figure 5 is a log-log plot of the score versus the number of contacts for single operator, class C contestants who made 100 or more contacts in the 1999 ARRL SSB contest.



The rules for this contest state that a US/Canada station earns contact and multiplier credits for working DX stations but gets no credit for working other US/Canada stations. Similarly a DX station earns credit for contacting US/Canada stations but gets no credit for contacting other DX stations. The rules divide the contest system into two separate and unique subsystems. This is illustrated in Figure 5 by the two distinct lines. Each group of competitors is described by a power law equation with different exponents. The higher exponent for the US/Canada contestants is mostly due to the fact that these contestants can work about 350 multipliers per band while the foreign stations could only work 62 multipliers per band (i.e. US and Canadian states/provinces/territories).

In order to demonstrate that the power law relationship between the scores and the number of contacts is a general and universal characteristic of a contest system I prepared Table 2 that is presented at the end of the article. This table gives the exponent of the power law, for a variety of contests, modes and categories. It also gives three statistical parameters (R^2, F-statistic and $P_{0.05}$) that are measures of the goodness of the power law relationship. Note, that in order to ensure that the power law relationship was determined for true contest participants, and that casual participants did not unduly influence it, a minimum of either 100 or 200 contacts, depending on the contest category, was used as the cut-off point for determining the parameters of the power law. The cut-off point is given in the table.

6. What does it mean?

Let me summarize the observations that have been made so far. First, we notice that some things in a contest are under a contestant's control and other things are not. The number of contacts a contestant makes is not only determined by the operator's skill, geographical location and equipment but it is also determined by a variety of natural forces and the collective activities of the other participants. The overall nature of each contest emerges over time as these predictable and unpredictable processes combine to shape its character.

Secondly we found that once a contest is over and its complete character has emerged we can use mathematical techniques to measure some of its characteristics. For example, for a given subset of participants in a contest we can calculate the exponent of the power law relationship between scores and total numbers of contacts. This relationship gives us the average expected score for a given number of contacts given the overall character that emerged during the contest. Using this relationship each participant can determine if their score is above or below the expected average score given the number of contacts they made. In other words, this gives a participant a relative measure of performance given the number of contacts made independent of their geographical location, setup, total operating time and skills.

7. Where to now?

For some time there has been an ongoing debate about the role that the contest community plays within the general amateur radio community. More recently there has been some discussion about moving some of the information that has been traditionally printed in magazines to the web. I would like to suggest that by moving the detailed contest results to the web, and leaving much of the descriptive material in the magazines, we might be able to accomplish something unique.

First, simply placing the contest results in a publicly accessible web database will allow us to do some simple analyses similar to the one presented in this article. This would help us gain a deeper understanding of the overall character of the worldwide contest community. The major difficulty that was encountered during this investigation of information for this article was the poor availability of contest data in digital format. In fact, it took close to 100 hours to digitize and sanitize the CQ WW data from the CQ Magazines. It seems strange that the contest results are not archived in a database, especially given the fact that contest logs are usually submitted by email or on diskette. If summary contest results were available in a database form, the parameters for the power law relationship between the score and the number of contacts could be quickly calculated. With these parameters and a simple JavaScript a contestant could visit the website, select the contest category in which he competed and enter the actual number of contacts that he made. The JavaScript would return his expected score. Thus, given the amount of time a contestant participated in a contest and the setup he had, this would allow him to determine relatively how well he did given the nature of the contest system. Who knows, research in this area might result in the long sought after Holy Grail - a technique to calculate an equalized amateur radio contest score.

However, there is a more important opportunity. The study of natural and social nonlinear, dynamic systems is relatively new. The depth to which researchers can investigate these systems depends on the quality of the data that they can collect. While it is relatively easy to collect accurate date about physical systems (e.g. the motion of objects and the flow of fluids) it is quite difficult to collect accurate data about social activities.

Amateur radio contesting is a social activity. Like all social activities it is performed within the limitations imposed by the laws of nature. However, unlike most social activities, we keep an accurate log of our activities. In fact most of our contest logs are accurate to the minute, our physical location can be uniquely identified with a maidenhead locator, and the fact that a point-to-point communication was made on a certain band at a certain time can be validated. We have within our collective logs, a set of accurate data describing a social activity - amateur radio contesting. Further more, this data is collected almost monthly in a variety of contests. In fact, it is probable that within a variety of amateur radio organizations we already have an archive of valuable information.

There is one additional factor that makes our logs even more unique. While it very rare to find accurate data that describe a social activity, it is more rare to find data about a social activity that can be directly correlated with information about some natural dynamic processes that took place at the same time. Consider the fact that during a contest there are dozens of ground and satellite based instruments collecting, among other things, propagation and solar activity data. For example, a relatively simple thing that could be explored would be how the exponent of the power law relationship changes with the sunspot cycle. I have only touched on some of the simple things that can be done. There are many more powerful analytical techniques in the nonlinear dynamics research community that may give us an even more profound insight into what we do and how nature affects it. I suspect that our contest logs may be quite valuable indeed, and could be used by the scientific community to gain a deeper and more profound understanding of natural and social activities.

In conclusion, perhaps if we made our contest logs publicly available in a web database then within the long-standing traditional spirit of amateur radio we might be able to make a novel contribution to the scientific community. Some contestants may object to this notion because it might make them feel somewhat exposed having their logs publicly available. I would like to point out that accurate data should include records of human error and foibles. Accurate unprocessed data are sometimes more valuable than sanitized data. In fact, this exposure also means that we can independently verify contest results. We can test and improve current log processing tools and perhaps develop new ones. Making our contest logs publicly available might allows us to find other ways to make important contributions to our own community and the world at large.

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Appendix 1

Is the ARRL Sweepstake a nonlinear, dynamic contest?

Does the popular ARRL Sweepstakes contest and others like it have a characteristic that makes them different from most DX contests? Recall that in the preceding article the relationship between the score (S) and the number of contacts (Q) is generally given by

$$S = c\,Q^n$$

Also, recall that if every contact produces a new multiplier then the exponent, n, in the above equation would be equal to 2.0. On the other hand for a contest where there are no multipliers the exponent, n, would be equal to 1.0. In other words, for a contest with no multipliers the score simply increases linearly with the number of contacts.

I think we all will concede that the ARRL SS contest is a dynamic contest since it meets all of the criteria for a dynamic contest discussed in the article. Is the SS a nonlinear contest? In order to answer this question let me begin by making a simple observation. The more multipliers there are in a contest the less likely the possibility that a contestant will work all of the multipliers. On the other hand, the fewer multipliers there are the more likely a contestant will work all of them. In fact, in the ARRL SS contest many participants work all of the possible multipliers.

A close examination of Table 2 shows that the WPX contest has the highest exponent for the power law. This contest has a very large number of potential multipliers. On the other hand, for the DX side of the ARRL DX contest, a contestant is more likely to work all the ARRL sections on all the bands. Notice that the exponent is lower. In general, the exponent is higher when the potential total number of multipliers is higher and the exponent is lower when the potential total is lower.

After reading my article, Pete, N4ZR, pointed out that some SS contestants work all ARRL sections within the first 12 hours or so and after that their scores simply increase linearly at a rate of 160 points per contact. Does this mean that the SS contest is not a nonlinear contest?

Figures A1a and A1b are graphs of the results for the 2000 ARRL SS CW and SSB contests. These graphs explore the relationship between scores and contacts for power class A contestants who made more than 100 contacts. The red line drawn though the points assumes that the contest is a linear contest (i.e. n = 1.00) and the blue line assumes that the contest is not linear. In both the CW and the SSB case the exponent of the power law for the blue line is 1.17-1.18. Notice that below about 300 QSOs the blue line fits the data points better than the red line. However, above about 300 QSOs the red line fits the data points better than the blue line. What does this mean?

The ARRL SS contest is atypical of many contests. It starts off as a nonlinear contest and the closer a participant gets to having worked all the ARRL sections the more linear it becomes. Precisely at the point where all of the sections have been worked the ARRL SS changes into a perfectly linear contest and from that point onwards a contestant's score increases by 160 points with each additional contact.

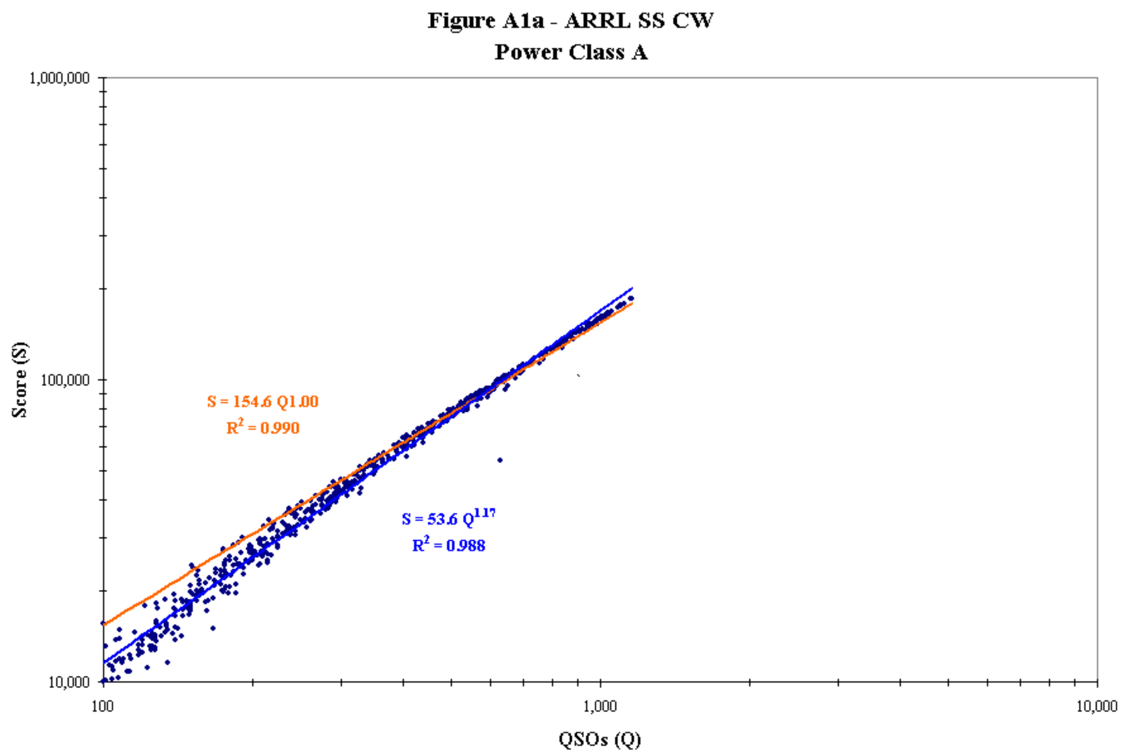

Figure A1b - ARRL SS SSB
Power Class A

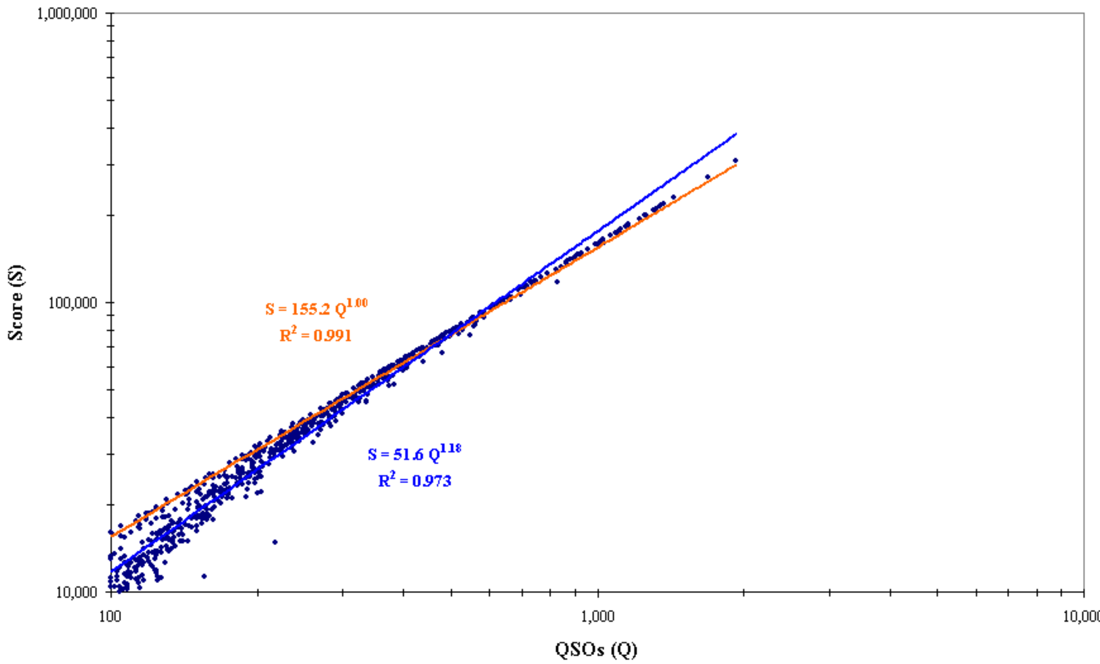

Table 2 - Slope and Intercept values for a variety of contests, modes and classes

Contest	Region	Mode	Power	No. Contestants	Min. No. Contacts	Slope	y-intercept	R^2	F statistic	$P_{0.05}$
1999	All	SSB	QRP	51	100	1.63±0.06	9.91±1.45	0.93	671	0.0001
CQ WW			LP	651	200	1.56±0.02	15.47±1.16	0.87	4,209	0.0001
			HP	596	200	1.47±0.02	31.08±1.11	0.94	8,786	0.0001
			All	1280	200	1.53±0.01	19.73±1.09	0.91	14,669	0.0001
		CW	QRP	99	100	1.65±0.06	8.51±1.47	0.88	676	0.0001
			LP	655	200	1.53±0.02	18.02±1.16	0.87	4,374	0.0001
			HP	551	200	1.47±0.02	30.05±1.13	0.92	6,367	0.0001
			All	1280	200	1.52±0.01	20.67±1.10	0.90	11,741	0.0001
1999	US-Canada	SSB	A	22	100	1.69±0.08	7.26±1.60	0.96	447	0.0001
ARRL			B	223	200	1.55±0.02	17.34±1.15	0.96	4,835	0.0001
			C	257	200	1.49±0.02	27.44±1.11	0.97	8,787	0.0001
			All	497	200	1.52±0.01	22.12±1.08	0.97	15,398	0.0001
	DX	SSB	A	12	100	1.52±0.05	15.33±1.31	0.99	1,075	0.0001
			B	130	200	1.40±0.02	27.72±1.14	0.97	4,401	0.0001
			C	125	200	1.40±0.02	27.53±1.12	0.98	7,263	0.0001
			All	265	200	1.40±0.01	28.13±1.08	0.98	14,885	0.0001
	US-Canada	CW	A	46	100	1.65±0.04	9.15±1.24	0.98	2,007	0.0001
			B	226	200	1.50±0.04	25.15±1.10	0.98	10,205	0.0001
			C	192	200	1.42±0.02	39.94±1.11	0.98	8,983	0.0001
			All	448	200	1.45±0.01	34.45±1.07	0.98	21,151	0.0001
	DX	CW	A	38	100	1.60±0.03	9.23±1.21	0.98	2,257	0.0001
			B	263	200	1.46±0.01	22.91±1.07	0.99	17,830	0.0001
			C	189	200	1.43±0.02	25.73±1.11	0.98	9,190	0.0001
			All	475	200	1.44±0.01	25.36±1.06	0.98	29,208	0.0001
2000	All	SSB	QRP	34	100	1.89±0.07	2.92±1.47	0.96	835	0.0001
CQ WPX			Tri-band LP	76	200	1.75±0.03	7.35±1.21	1.00	3,149	0.0001
			Tri-band HP	72	200	1.67±0.02	12.67±1.17	0.99	4,872	0.0001
			SO	667	200	1.69±0.01	10.03±1.07	0.97	24,992	0.0001
			All	838	200	1.70±0.01	9.90±1.06	0.98	32,763	0.0001
	All	CW	QRP	51	100	1.78±0.04	5.51±1.30	0.97	1,625	0.0001
			Tri-band LP	107	200	1.61±0.02	16.39±1.16	0.98	5,170	0.0001
			Tri-band HP	25	200	1.64±0.04	15.40±1.33	0.99	1,481	0.0001
			SO	457	200	1.64±0.01	13.40±1.09	0.98	20,649	0.0001
			All	627	200	1.64±0.01	13.52±1.07	0.98	27,160	0.0001

Notes:

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[1] Some ideas presented in this article were originally developed and presented by the author in a series of scientific publications on complex, scale-independent (i.e. fractal or self-similar) systems in nature and society available at http://www.sussex.ac.uk/spru/jskatz

[2] There are a few exceptions like the CQ WW contest where there is no contact credit given for working a station in your own country but it might be worth a country and/or a zone credit.

[3] If the value of a contact changes depending on with whom the contact is made and/or a multiplier is worth more than 1 point the constant *c* will represent the product of the average contact value and the average multiplier value.

[4] The general form of a power law is given by the equation $y = a\,x^n$ where *a* is a constant and *n* is a real number. Sometimes this relationship is also expressed in its logarithmic form as $log\ y = b + n\ log\ x$ where $b = log\ a$.

[5] In fact this is a very nonlinear relationship. Prof. Leon Katz showed that the relationship between multipliers and contacts can sometimes be approximated by $M = c\,Q^{p - s \log(Q)}$ where c, p and s are constants that are adjusted to produce the best fit to the actual data.

[6] There are many excellent references to this idea. Two popular references written with a minimum amount of mathematical detail are *Chaos: Making a New Science* (Viking Penguin, 1987) written by James Gleick and *The Quark and the Jaguar: Adventures in the Simple and the Complex* written by the Noble Laureate, Murray Gell-Mann.

[7] Benoit Mandelbrot discovered that noise does not occur in a steady stream but in *bursts with gaps*. Furthermore the *bursts* of noise are also composed of *bursts and gaps*. He concluded that *pure noise* does not exist and in fact that noise pulses follow a fractal pattern called *Cantor Dust*. (see Mandelbrot, B. *The Fractal Geometry of Nature*. New York: Freeman, 1983 and http://linkage.rockefeller.edu/wli/1fnoise/).

[8] The data is available at http:// ourworld.compuserve.com/homepages/n8bjq/99CWSCORES. PDF

[9] A real number is any number between +infinity and -infinity.

[10] The statistical procedure that was used was a simple linear regression using the least squares technique.

[11] The analysis was performed on the scores and number of contacts for 588 contestants. The slope = 1.75 +/− 0.01, Y-intercept = 6.54 +/− 1.05, $r^2 = 0.988$, F =48,032 and P (0.05) < 0.0001. The statistical details for the regression analysis of a number of major contests are given in Table 2.

[12] A system with a power law relationship suggests that it has some scale-independent, self-similar or fractal characteristics. For more information see reference 7 for further reading material.

[13] We will only explore changes in the exponent and not changes in the intercept. For a variety of reasons that are not relevant to this article little or no practical significance can be attached to the value of the intercept.