Circuit Merit Signal Reporting Explained (de Jim Aspinwall, NO1PC)

Introduction

This paper is intended to provide reference to the "circuit merit" method of expressing received signal quality, as well as illustrate the technical factors relative to received signal strength. "Circuit merit" provides an easily perceived plain-language description of reception from another station – be the mode AM, FM, SSB or CW.

Circuit Merit Descriptions

Circuit Merit #	Explanation	Note
CM5	**"Loud and *clear*".** Completely clear, broadcast quality. Each word is fully understood, ***without any interference or noise***; on FM, full quieting. Always breaks squelch (FM.)	This designator is not always earned on FM, and ***seldom on SSB***; as conditions must be superb. (*** >20 dB/>5 S-unit difference between noise and received signal.)
CM4	**"Good readable."** Clear with a slight amount of noise and/or interference. ***Each word is understood***. Always breaks squelch (FM.)	***A common report for solid SSB voice under very good conditions***; the FM equivalent is a slight amount of "white noise". (*** 12-20 dB/3-4 S-unit difference between noise level and received signal.)
CM3	**"Fair readable."** Some noise, static and/or interference may be present. ***Bulk of transmissions are understood without having to be repeated.*** Usually breaks squelch (FM.)	CM3 is generally considered to be at the margin of acceptable voice Communications, particularly when using squelched FM. (*** ~ 10 dB/2 S-units difference between noise and signal level.)
CM2	**"Weak but readable."** The noise level very close to signal level. Static and / or interference very prevalent; words are missed, ***retransmissions are necessary***. Will not open squelch reliably (FM.)	CM2 is not considered not acceptable or reliable.
CM1	**"Unreadable."** A signal is barely evident and words are unintelligible. You can tell that someone is "there" (SSB) but will not break squelch(FM.)	CM1 is deemed unusable for voice communications.
CM0	**"Nothing heard."** Absolutely no signal is detectable.	

[*** dB/S-unit values explained in the following technical pages]

Rule of Thumb

Keep it simple – qualitative not quantitative. Circuit Merit is provides accepted descriptions/perceptions of signal quality are shared among many sources/users.

There are no fractional qualifiers necessary or meaningful in circuit merit designations – the received signal is either CM5, CM4, CM3, CM2, CM1 or CM0. A "strong Circuit Merit 4" is just Circuit Merit 4. Circuit Merit 4 is a VERY good, impressive, reliable signal for SSB. Circuit Merit 5 is rare in a majority of the SSB operations. That is to say – no one should routinely issue a Circuit Merit 5 rating for SSB.

Getting Technical

There are a handful of parameters and measurements that could better qualify the perception of the receiving operator – but who has time for S-units, decibels or microvolts when you're just trying to get or provide help?

The technicalities are important when preparing to be able to communicate to provide help. They will tell you about your operating environment, antenna conditions, receiver conditions, etc.

As described and perceived – *Circuit Merit 5 is nearly impossible to achieve with HF/SSB operation*. Unlike FM, AM and SSB do not present full-time carrier power across the entire bandwidth in use (2-3 KHz) though our receivers provide/allow us to hear any signal within that bandwidth. What is not transmitted voice energy at a specific frequency to cover up spectral noise, leaves room for us to hear both desired voice and background noise. AM and SSB are almost never without background noise.

In addition to S-5 or "10 over S9" signal reports you've probably heard many times operators referring to an S-3 or S-9 noise level in relation to discussion about the received level of another operator's transmission. These values translate directly to operating, equipment and atmospheric/spectral conditions at the moment.

S-units (signal strength) are a relatively simplified numbering scheme to take the complexities out of adding, subtracting or scaling microvolts and decibels. S-units have very specific microvolt and decibel signal values, and reviewing these values can give us many clues as to noise levels versus received signal quality.

We can use these values to better understand what's happening from the rig out to the atmosphere. The microvolt or decibel values are significant to compare, contrast and know the spectral/band conditions and the receive capability of receivers.

For this we need to understand the detection limits or receive sensitivity of our receivers, the level of noise, and acceptable/detectable desired signal differences between them.

We could also draw some correlations between either S-units, microvolts or decibels, and Circuit Merit values if we can factor the difference between no-signal noise levels and sign-present strength levels. There are numerical correlations between good and bad signal levels.

This is where being able to understand the number of S-units of the received signal versus the S-unit value of no signal background noise could be useful. For instance an S7 received signal amid an S5 background noise level (difference of 2 S-units) is probably not so good, but an S7 received signal amid an S3 noise level (difference of 4 S-units) is probably quite acceptable.

S-Meter Readings

As shown in the table below, S-units equate to very specific measurable values of signal voltage and power. These values are determined standards assigning specific S-values to specific measureable signal levels in laboratory or field conditions.

For these numbers to have any real meaning other than "I can hear you" or not, we need to know a little more about our receivers, and understand the impact of background/spectral/atmospheric/man-made noise.

S-Meter Units	Signal Level µV (50Ω)	Signal Level dBm	dB above 1uV
S9+10dB	160.0	-63	44
S9	50.2	-73	34
S8	25.1	-79	28
S7	12.6	-85	22
S6	6.3	-91	16
S5	3.2	-97	10
S4	1.6	-103	4
S3	0.8	-109	-2
S2	0.4	-115	-8
S1	0.2	-121	-14

From this you can see there is approximately a 5-6 dB difference between S-units, or one S-unit is 5-6 dB above or below the next. Any 2 S-units are approximately 10-12 dB.

Receiver Sensitivity

How well your receiver can detect, and present usable intelligence (typically voice) to your ears for good comprehension begins with a value of receive sensitivity.

Typical receiver sensitivity for HF radios, be they Icom, Kenwood or Yaesu ham equipment or commercial Motorola or Harris gear is in the realm of 0.15uV from 2-30MHz. This is roughly the same value for most VHF and UHF FM radios. This equates to roughly -123 dBm, 2 dB below an S-1 measurement.

Although you may think such a receiver could 'hear' an S-1 signal, and it might, in order to get any intelligence out of such a weak signal would require a VERY low background noise level or a really good signal processing scheme. As powerful as the human brain may be, the hearing system can't always provide the brain enough clarity to process weak signals.

Detectability

Bear with me here – this is where real numbers start to add up to Circuit Merit.

For humans to 'hear' something and make use of it requires the desired signal to be some significant level above the noise. This is where another value, signal-to-noise ratio, comes into play. Humans can usually determine something audible of value if it is at least 6dB different than other audible energy.

Most radios have a detectable (presenting useful transmitted information to the user) signal-to-noise ratio of 10 dB. This equates to requiring at least an S3 signal above absolute minimal noise for us to understand the transmission.

Who would think an S-3 signal is good? In reality we VERY rarely ever encounter a background RF or environmental/atmospheric noise level of -123 dBm or lower. As I look at the pan-adapter and S-meter of my HF rig my typical averaged noise level ('floor') on 20 meters runs about S5-S6, or -100 up to -91 dBm.

Reasonably pleasant signals rise to -85 up to -80 dBm, or S-7 to S8 – or 10-15 dBm above the noise level. *Hmmm… signal to noise ratio of 10 dBm !!!*

S-Units and Circuit Merit

We could extract from this that perhaps a Circuit Merit 3 ("fair readable") signal equates to any received signal that is 10db or higher above the noise. This could then be evaluated for someone who is 10 dB over S9 when the noise level is S9.

A Circuit Merit 4 signal ("good readable") would then be much higher than a mere 10 dB above the noise level.

This > 10 dB value runs coincident with one other value used more in FM than AM or SSB – SINAD – "Signal to Noise and Distortion". A fair to good readable FM signal is measured at 12 dB SINAD – exhibiting some but not bothersome hiss/white noise (Circuit Merit 4.) An excellent FM signal of "full quieting" or no noise is measured at 20 dB SINAD (Circuit Merit 5.)

If you are stuck on the numbers on the meter versus what your brain tells you is acceptable usable communications quality to come to a Circuit Merit value then you have to evaluate the average S-unit display of the transmitted signal minus the noise level – it takes a 2 S-unit difference to make a Circuit Merit 3 signal, 3 or more S-unit difference to make a Circuit Merit 4 signal, and over 4 S-unit difference to even think about a Circuit Merit 5 evaluation.

By the numbers and typical conditions, it is VERY rare that we will encounter received SSB signals that are (20+ <u>*over noise*</u>, not just what the meter reads) Circuit Merit 5!