CATCH A FALLING STAR....

Shelby Ennis, W8WN

Introduction

In the past 2 years I have picked up approximately 60 new grids on 144 MHz, giving me a total of about 350 grids confirmed on 2 meters. Some of these new grids were worked during the great auroras we've had during this sunspot cycle peak, and a few by other types of propagation. But most have been worked using high speed meteor scatter - not during the big showers, but any day of the year, whenever I could find a station operating from a new grid. The main reason I haven't picked up more new grids is because they haven't been available, or because I didn't have time to get on the air. Any station normally equipped for VHF DX operation can do similarly. N8OC recently picked up 28 new grids and 6 new states in about a week, and several other fellows have picked up about 20-30 new grids on 144 MHz in only one month. K9KNW, EL95, has picked up 89 new grids since HSMS became available over here. K4SSO, EM48, jumped from 50 to 115 grids on 2 meters in less than a year, due primarily to *WSJT*. WØDB writes, "I would also like to report on a [2 meter] portable operation I did. From Dec. 31 to Jan. 3 of 2002 I was portable in grid square EN15, South Dakota, running WSJT with 100 watts to a home-brew 4 element. quad I built while there at my parents' home, at a height of about 20 ft. I was able to complete 10 of 11 WSJT skeds I ran while there. I was stunned that I made so many QSOs with that modest setup. Some of these were made in less than 10 minutes - but in no case were pings long enough to have completed a QSO with SSB." And Klaus, DJ5HG, wrote to K1JT: "Sorry, I did not have the time to be active at the Leonids. But I let your WSJT run on 144.370 MHz with an omnidirectional antenna. The *decoded.cum* file recorded 24 DXCC-countries in one night. No aurora, no Es and no tropo ever produced such conditions. The WSJT worked so nice that many hams called CQ including the full locator or they sent it with the 73."

A brief history of the time of meteor scatter

Meteor scatter operation began in 1953 when Paul Wilson, W4HHK, in western Tennessee (***QST***, Feb. 2000, p 75) and Ross Bateman, W4AO (NE Virginia) kept hearing bursts of signal while trying to work during a widespread tropospheric opening. They, along with W2UK, W5RCI, W2NLY, W2AZL, W1HDQ, W1FZJ, and others were soon running tests, establishing how communication could be done using this mode (Emil Pocock, W3EP, ed., ***Beyond Line of Sight***, pp. 95-96 and pp. 104-105. With the publication of two articles in *QST* by W4LTU (Walter F. Bain, W4LTU, "V. H. F. Meteor Scatter Propagation," ***QST***, April 1957, pp. 20-24, 140, 142, 144; and "VHF Propagation by Meteor-Trail Ionization," ***QST***, May 1974, pp. 41-47, 176; the latter also reprinted in *Beyond Line of Sight*, pp. 108-115), meteor scatter became a popular mode for making contacts beyond the normal extended-tropo range. During the annual Perseids meteor shower, even though stations were well spread out, enough were active that QRM sometimes became a problem at times. (Everyone was crystal controlled, and there was no way to use a "calling frequency" in those days.) Using various means of keying and two- or three-speed reel-to-reel tape recorders, some managed to operate at speeds up to 100 wpm, slowing the tape for copying.

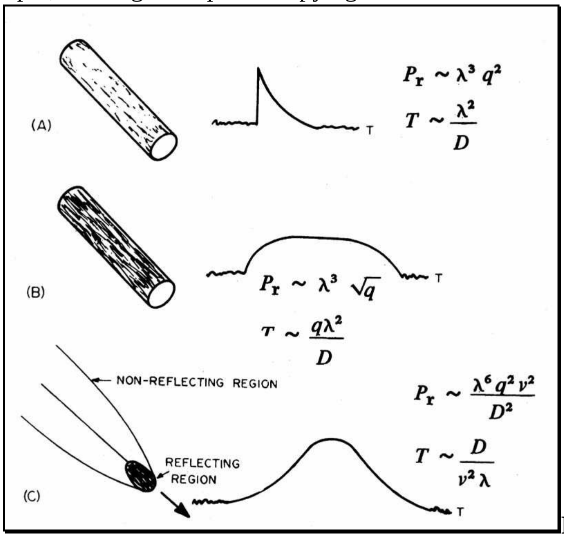


Figure 1 - Underdense, overdense, head echo

It has been asked why the research institutions, government, and military had not used meteor scatter operation prior to this time. Also, did the early pioneers (especially W4AO) know about communications tests run during this same period? Most of the early non-Amateur experiments had been done using back scatter and generally relied on overdense burns. However, the possibility of communication using this mode did suggest itself, and it is known that several groups did a few communication experiments prior to 1953. By 1958, several meteor scatter communications circuits had been set up. OH5IY has done a lengthy study of the history of meteor scatter, and has collected a large amount of information on the subject. In addition to the history of meteor scatter, his papers also give the best treatment of the theory and use of meteor scatter operation that is easily available. Anyone serious about

MS needs OH5IY's papers and also his MS prediction and "effectivity" meteor scatter program, *MS-Soft*, available at ***http://www.sci.fi/~oh5iy/***. (For more history, also see D. W. R. McKinley, ***Meteor Science and Engineering***, McGraw-Hill, 1961.)

In spite of tests by the government and several institutions, it was Amateur Radio that brought the real possibility of meteor scatter communication to the notice of others. However, most of the time the "pings" that Amateurs received were few, short and weak. As SSB operation became more common on VHF in the 1970's, North American Hams saw an opportunity to push across a greater amount of information in the same amount of time. Using SSB, it was possible to exchange information as rapidly as even the best operators, using multiple-speed tape recorders, could on CW.

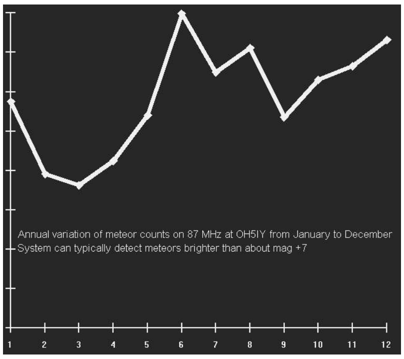


Figure 2 - Annual variation of meteor counts, 87 MHz, from OH5IY

But SSB operation still required pings of one second or longer to be useful. On 144 MHz, these almost never occurred except during the peaks of major meteor showers. (On 50 MHz, where pings are longer and more frequent, SSB MS contacts can be made routinely by well-equipped stations.) So nearly all North American 144-MHz MS operation occurred only during the "big three" meteor showers each year (the August Perseids, December Geminids and January Quadrantids). Outside of the 3 major showers and a very few minor showers, there simply was no MS operation in North America.

Meanwhile, the Europeans had a different idea. SSB meteor scatter operation was much too slow to utilize the barrage of tiny meteors that constantly strike the earth's protective atmosphere. Their pings, while numerous, are usually weak and very short, being caused by scattering from the underdense ionization left by the tiny particles. The European idea was to transmit CW at much higher speeds using an electronic keyer, record incoming pings on a modified audio cassette recorder, which could then slow the pings down to a high but readable speed. Using this method, speeds up to 400 wpm (or 2000 lpm; lpm, letters per minute; lpm=wpm x 5) or faster were quickly achieved. European operators soon were routinely making contacts every morning of the year and logging dozens during meteor showers, while North Americans were doing nothing.

Even though the modification to an audio cassette recorder was simple, this type of meteor scatter operation (now called **HSCW** - high speed CW meteor scatter) did not cross the Atlantic. North American Hams somehow felt that SSB was superior to any type of CW. Several operators attempted to create interest in HSCW in the Western Hemisphere, but few if any contacts were made. It's difficult to make a contact when you're the only one operating!

HSMS finally crosses the Atlantic

HSMS in North America started almost by accident when, in May 1997, Steve, KOØU (now KØXP) and W8WN learned that each liked CW MS operation. At this same time, DL3JIN's ***SBMS*** ("*Sound Blaster Meteor Scatter*") receiving program, which allowed a computer to emulate a variable-speed tape recorder, was discovered. Several schedules were run at speeds up to 80 wpm using a programmable keyer or OH5IY's *MS-Soft* program. W8WN was using *SBMS* to assist with receiving, while KOØU copied by ear at speed. (*SBMS* was an excellent program, yet it never caught on either in Europe or North America, for reasons unknown.)

Early in August of that year, **9A4GL**, Tihomir Heidelburg, a college student in Croatia, released the first Beta DOS version of his HSCW receiving program, ***MS_DSP*** ("*Meteor Scatter using DSP*"). It was not as well developed as DL3JIN's program, but it had several additional features that showed great promise. E-mail messages began to fly back and forth across the Atlantic as Tihomir sent us version after version of *MSDSP* to test, eventually adding nearly every feature that we requested! Before the peak of the Perseids that year (1997), a test version with transmit capability was available, and speeds immediately jumped to 2000 lpm (400 wpm) among the handful of Beta testers. Other stations learned of the HSCW experiments and began to join the fun. Routine speeds soon were up to 4000 lpm (800 wpm), and an experimental contact between Valerie, WD8KVD (visiting in EM77), and KOØU (FN42), was made at 8600 lpm (1720 wpm), the highest speed then possible (*QST*, April 1998, p 38). The next year (1998), while again visiting in Kentucky for Christmas, WD8KVD and KOØU made a contact on Christmas Day at the unheard-of speed of 16,600 lpm (3320 wpm), which is still the record speed. (***http://www.qsl.net/w8wn/wd8kvd/wd8kvd2.html***).

Some operators had trouble using the DOS *MSDSP* program, as they were familiar only with Windows. (The DOS version of *MSDSP* also requires a fully compatible SB-16-type audio board.) So in 1999 Tihomir released his first Windows 95/98 version, ***WinMSDSP 2000***. With more features and capabilities, it was quickly downloaded by a number of VHF operators around the world The Windows version was almost identical with the DOS version, but with several additional features. It runs under Win95/ 98/ME (though W95 may require some additional or updated Microsoft files), and runs with most audio boards that support DirectX, although certain boards (especially the SB-64) cause problems.

WinMSDSP also included a limited decode feature, in which the program attempts to actually decode the CW signal and display the characters on the screen. While this feature works to some extent, it requires much longer, stronger pings than are normally available. This feature is thus considered only an experimental plaything by most operators (who were amazed that it worked at all!)

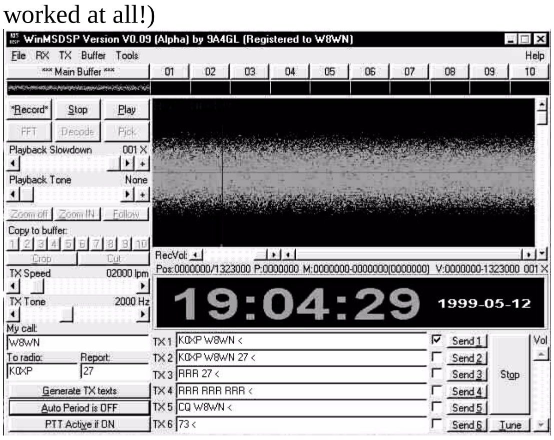


Figure 3 - B & W picture of WinMSDSP

During 1997 and 1998, the *MSDSP* Beta test group had also been testing various techniques for HSCW MS operation. It soon became apparent that the procedures in use for slow CW or SSB meteor scatter were inadequate for HSCW. The Europeans, with their 20 years of HSCW experience, had developed many additional ideas. However, some of their customs were different from ours, and it's hard to suddenly change 40 years of operating experience. Many of the schedules between W8WN and KOØU were devoted to testing various procedures, speeds, techniques, and equipment settings. This is one reason that the percentage of completed contacts did not increase as rapidly as would be expected from the increasing speeds. (It should be noted, however, that even though most schedules between W8WN and KOØU were not aimed at necessarily completing a contact, yet the percentage of completions, day in and day out, averaged about 80%, with a 94% completion rate during favorable times of year). For more data on these test schedules, see the "Real Old News" pages on the W8WN Web site at ***http://www.qsl.net/w8wn/hscw/papers/realold.html***.

Unfortunately, *MSDSP* and *WinMSDSP* are no longer supported. Tihomir experienced a major hard drive crash which wiped out all of the source code. The program can still be downloaded from several Web sites, and it works as well as it ever did. At this time, it is the only easily available way to operate HSCW MS. There are other methods, but they are either expensive, difficult to obtain, or are hard to use (see the various HSMS Web sites for information on using *Cool Edit*, the German DTR, etc.). It is not known if Registration numbers are still available for *WinMSDSP*. They should be, but it will require an E-mail to Tihomir to be sure. (*WinMSDSP* runs for only 15 minutes at a time, and has to have its parameters reset each time, when used unregistered). A problem with *WinMSDSP* is that it will not control the computer serial port transmit line under Win 2000. There is a program, *DIRECTIO.EXE* (***http://www.powerbasic.com/files/ pub/tools/win32/***) that is said to allow the com port to work under Win2000, but nothing more is known about this (see the W8WN MS "*Hot News*" Web page and also the notes and papers concerning *WinMSDSP* for more). Most who run Win2000 use VOX to control the transmit line. (*WSJT* controls the com port properly with all current versions of Windows).

For those without enough serial ports, L-Com (800-350-5266) sells (or sold) the IOGear USB/Serial Adapter. It is not listed in their catalog, so a phone call would be required to see if it is still available. They also sold boards that would add additional serial ports to your computer.

MS operation goes digital

Last year (2001), Nobel Prize Laureate Joe Taylor, K1JT (***http://www.nobel.se/physics/laureates/1993/ taylor-autobio.html***), and I had a small argument via E-mail. I contended that, with the computers in common use in Ham shacks at the turn of the century, they could not beat the ear-brain combination for decoding very weak, very short high-speed MS signals. Joe contended that such a program could be written. So we argued for about two weeks, then Joe set out to prove me wrong.

Joe is experienced with Unix, but had never written a program under Windows. In the next month he produced several versions of a DOS program to first test make-break keying, then three- or four-tone FSK. He would send me a test signal while I transmitted in HSCW, letting him know when I had several good pings of each part of the text. These would be E-mailed back to him for decoding and analysis.

After about a month of these tests, Joe was ready to try an operational Windows version. Joe made several more modifications of the decode algorithm, then it was time to offer it to the former *MSDSP* Beta Test Group for evaluation. Another month of testing, and it was released to the HSCW community, then to the world. And so ***WSJT*** ("*Weak-Signal communications by K1JT*") transmitting **FSK441** for high-speed meteor scatter was born.

The Europeans at first hated the program - they said it was too much like packet or RTTY, and wasn't "real MS" operation. But they grabbed it and used it anyway. Within two weeks of its release, there had been over 500 downloads by Europeans, and the numbers kept climbing rapidly. In North America, everybody loved it, but few downloaded it. The difference was in the huge number of VHF DX operators in Europe compared with the very small number in North America. At this time (early 2002), it appears that there are well over 1000 Europeans and about 250 North Americans using *WSJT*. HSCW activity is still strong in Europe, while FSK441 has almost completely replaced HSCW over here.

Like *MSDSP*, *WinMSDSP*, *SBMS*, etc., *WSJT* is a computer-assisted high-speed meteor scatter program. Unlike *MSDSP*, the computer program must also do the decoding of the 3-tone FSK signal. However, unlike some digital modes, especially packet, the operator is very much a part of the operation. Some have claimed that you could set up your computer and rig, walk away, and come back later to see whom you had worked. As quickly becomes obvious, claims such as these are made by people who have never bothered to even download *WSJT.* If you were to try something like that, you *might* find some text on your screen - showing you the station you failed to work because you were not available! Also, because all types of HSMS rely only upon the extremely short and weak underdense pings, a great deal of operator involvement is required to get the maximum amount of copy from what little signal is available. The human eye-ear-brain may not be able to decode an FSK441 signal - but the human is often much better than the computer in deciding whether it was an actual signal or just noise, and whether the copy is correct or if there are substantial errors in it. FSK441 has no error correction. Thus, without a large amount of involvement by the human operator, FSK441 MS contacts are impossible.

How does FSK441 using *WSJT* compare with HSCW? Very favorably. In fact, FSK441 is probably a little better than HSCW in sensitivity. It seems that Joe won his argument.

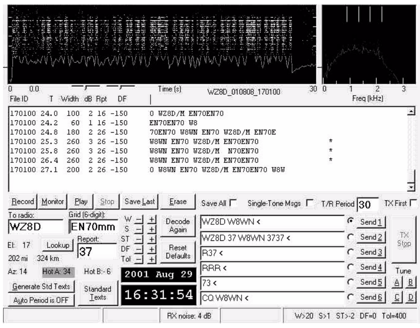


Figure 4 - B & W picture of WSJT

HSCW operation in Europe still uses relatively slow speeds - 1500 to 4000 lpm because a number of operators continue to use modified audio cassette recorders for receiving; and there are a lot of random CQs, requiring that all slow down to a speed usable by everyone. In North America, where all HSMS operation uses computers, the normal speeds have been 4000-6000 lpm, with more and more operation moving to 8000-10,000 lpm. FSK441 operates at 8820 lpm, and the loss in S/N ratio is not as bad as when using *WinMSDSP* at its highest speeds.

In a normal FSK441 message, each character is encoded as three audio-frequency tones sent sequentially. Each tone can have one of four possible frequencies, so the maximum number of encodable characters is 64. The timing of FSK441 is such that each dit of each character consists of exactly two full cycles of the audio tone at 882 Hz, three cycles at 1323 Hz, four at 1764 Hz, or five at 2205 Hz. The audio signal used by WSJT to generate FSK441 is spectrally clean and largely confined to the range of 660-2425 Hz, thus making effective use of the audio bandwidth of a modern SSB transmitter.

WSJT does not do as well with longer, stronger bursts as it does with weak pings. This is because it has been optimized for the tiny underdense pings, and work remains to be done on the receive algorithm for longer, stronger signals. It will hardly copy a weak tropo signal at all. But this may change if Joe is able to complete the JT43 section of *WSJT*, now in the works. For more information on *WSJT* and FSK441, see K1JT's *QST* article (*QST*, December 2001) and download the *WSJT Manual* from his Web site (***http://pulsar.princeton.edu/~joe/K1JT***). Also see the *WSJT FAQ* and the other HSMS papers on the HSMS/*WSJT* section of the W8WN Web site (***http://www.qsl.net/w8wn/***)

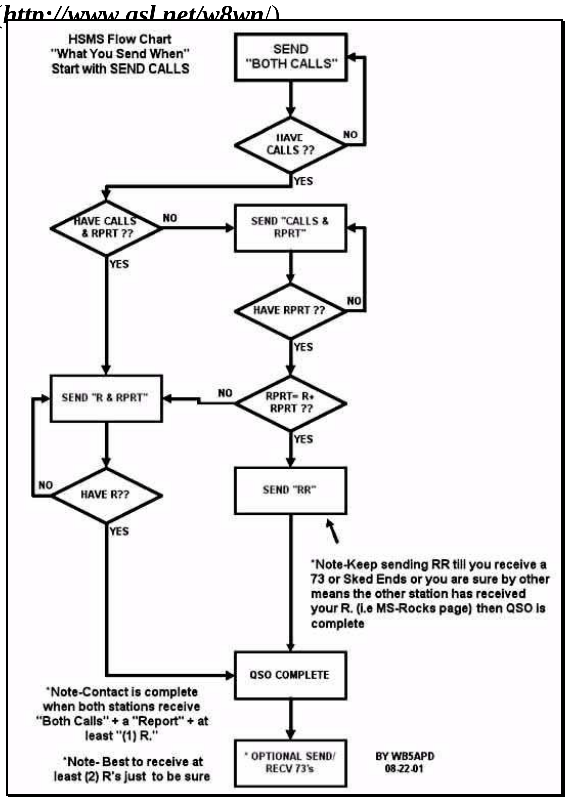


Figure 5 - "What You Send When" flow chart

Characteristics of HSMS operation

HSCW MS operation in North America now runs at speeds of 4000-10,000 lpm (800-2000 wpm). Nearly all operation is by schedule, with few routine CQs. This is because the number of North American stations capable of HSCW operation is still too few to provide many random contacts. The HSCW calling frequencies are **144.100** and **50.300** in North America. See the North American "*Procedures*" paper, available on the W8WN and other Web sites, for more. The Region I procedures can be found at ***http://www.scit.wlv.uk/vhfc/iaru.r1.vhfm.4e/5B.html*** Most schedules on this side of the Atlantic are made using the "Ping Jockey" (***http://www.pingjockey.net/cgi-bin/pingtalk***) and the "MS Rocks Live!" (***http://raven.cybercomm.net/~slapshot/dxing/hsms.html***) real-time Web pages, or via the HSMS Reflector (to subscribe, send message to ***hsms-request@mailman.qth.net?subject=subscribe***.

For FSK441, which is now the dominant mode of meteor scatter operation in North America (and probably in the world), the same Web sites and reflectors are used. FSK441 calling frequencies are **144.140** and **50.270**. (The 220 MHz frequency is still being discussed, as are the frequencies for all bands in Europe). Schedules are normally run between 144.105-144.140 and 50.260-50.300 MHz (the same frequencies as HSCW uses).

A station equipped for weak-signal operation on 144 MHz (150 watts or more, 14-element Yagi, and a decent VHF weak-signal location) has a good chance of completing a contact nearly any morning of the year using the underdense pings of sporadic meteors, **if** someone at a suitable distance is available for a schedule.

HSMS operation is very different from either slow CW or SSB meteor scatter operation. Both slow CW and SSB operation require **overdense** bursts or very good (i.e., strong, long and numerous) underdense pings to complete a contact. Unfortunately, overdense bursts are almost never observed except during major shower periods. (FM packet is not a weak-signal mode, thus is not usable for MS operation. The only other digital or quasi-digital mode that has had any success at all is the high-speed MS version of FeldHell which does a fair job on 50 MHz MS). HSMS relies on those very short (<0.5 second), weak pings scattered from **underdense** trains. Pings of this type are regularly produced by the "sporadic" meteors that bombard the earth constantly. Most of these are not fragments from the asteroid belt but are particles from dust trails left by ancient comets. Now they are widely distributed and no longer dense enough to produce recognizable showers. Their number may vary heavily day by day and even minute by minute. Most of these particles are tiny, no larger than grains of sand, or less, and generally much less dense. But because of their extreme speed, the ionization they produce as they enter the atmosphere is often enough to scatter or even refract a radio wave (Kenneth Davies, ***Ionospheric Radio Propagation***, U.S. Dept. of Commerce, 1965, pp. 351-376).

More about meteor scatter communications

Until late in 1997, all 144 MHz operation (and most 50 MHz operation) was confined to the 3 major showers - the August Perseids, the December Geminids, and the January Quadrantids. These 3 showers are reliable and have the highest rates of any of the annual showers. The Perseids and Geminids also seem to have a higher percentage of larger particles, giving rise to enough overdense bursts to make SSB worth while and even preferable near the peak times.

These and dozens of small showers are caused by periodic comets that have crossed the earth's orbit on their way around the sun, shedding debris in their orbit. (This general statement must be modified, however, for the December Geminids. Their parent body appears to be the Apollo asteroid 3200 Phaethon [perhaps a dead comet?])

When the earth in its orbit around the sun crosses the orbital path of the comet, it sweeps up some of the comet's debris. The closer this is to the time of the comet's passage, the larger the shower is likely to be. But most of the comets and showers are old, and their debris is now too sparse to produce much of a shower. The Perseids, Geminids, and Leonids are young enough to still produce good showers most years, yet they're old enough that the debris is well spread out along the comet's orbit Thus we don't expect much year-to-year variation. This isn't always true, of course, as the Perseids outburst of about ten years ago showed. Also, other, normally "minor" showers, sometimes produce great displays.

The big excitement for the past 4 years has been the Leonids. With the perihelion passage of the parent comet P.Tempel/Tuttle in February 1998, it was hoped that another "storm" such as we had in 1966 would be observed. While the 1966 rates (or the rates of some of the even greater Leonid storms, as in 1833) were not reached, the Leonids did briefly reach "storm" rates in 2001; and the so-called "fireball storm" of 1999 produced one of the most beautiful displays most of us have ever seen. If you weren't involved in any of these, the November 2002 peak is predicted to be the last major Leonid display in our lifetime (and probably for about a hundred years). The dust trail analyses of David Asher, Robert McNaught, Esko Lyytinen and others have brought the art of predicting the Leonids from a simple extrapolation from the previous year to a real science. So put November 19, 2002, around 0400 and 1040 UTC on your calendars! (2002 will not be a good year for visual observations because of interference from moonlight). And if you work only SSB, the "big 3" showers, plus one more year of the Leonids, are your only chances to do anything.

Over the millions of years of the solar system's existence, most of the comets that visit the inner solar system have evaporated and no can longer be found. But some of their debris still remains, and this gives rise to the background of "sporadic" meteors that constantly bombard the earth. Most of this dust is from comets, with an occasional chunk from the asteroid belt. They've recently discovered, however, that a little of it is interstellar dust - all the way from other stars! Most of the interstellar dust is too small to even produce an underdense ping. But when you're using sporadic meteors for communication, there's always the chance that you are using a part of another star! And you thought *Babylon 5* was far out.

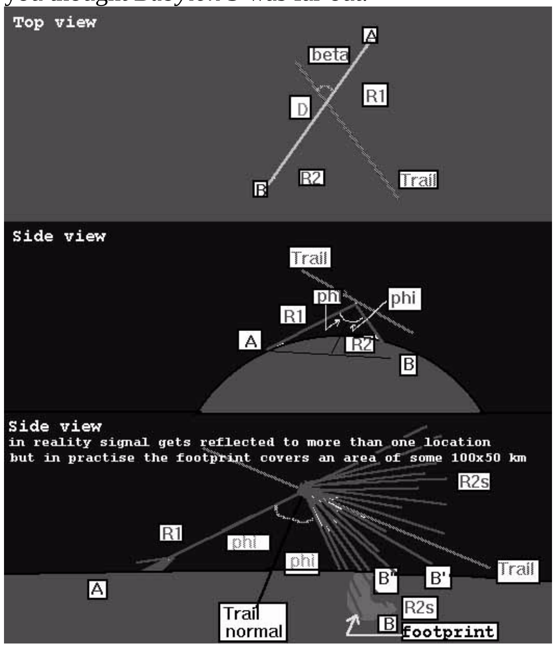
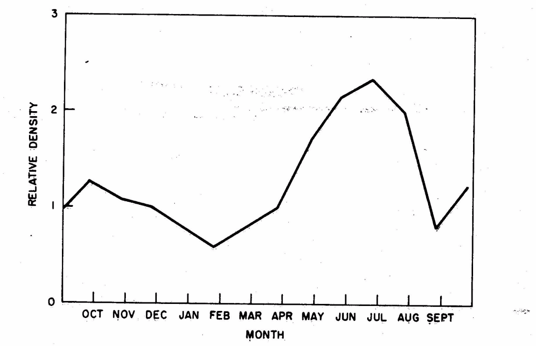


Figure 6 - Trail geometry

So what's the difference between the big overdense "blue whizzers," as they're sometimes called, and the tiny pings? It's the amount of ionization, which is related to the mass and velocity of the particle. The cosmic specks we're talking about are tiny. There is still uncertainty regarding the actual masses of the majority of the usable meteors, ranging from a tiny fraction of a gram to several grams. Their composition apparently varies from grains-of-sand type to "dustballs," with porous, crumbly material being the most common. But, because of their great velocity (from 11 km/s to 72 km/sec, or 24,600-161,000 mph, with a mean velocity of 45 km/sec), their kinetic energy is sufficient to produce the ionized train.

The underdense pings are produced when the ionization is sufficient only to scatter the impinging radio waves. But if the ionization is dense enough, the incident wave does not penetrate the column freely, and the wave is refracted, as though from a metal cylinder, giving a specular reflection. This is why even small stations can use overdense bursts, for they are nearly as effective as a sporadic E cloud. Unfortunately, overdense bursts are so rare outside of the peaks of major showers that they are worthless for routine communication on 144 MHz.



GURE 8.3. *Variation of space density of meteors along the earth's orbit.*

(After G. S. Hawkins, 1956, Monthly Notices Roy. Astron. Soc. 116, 103.)

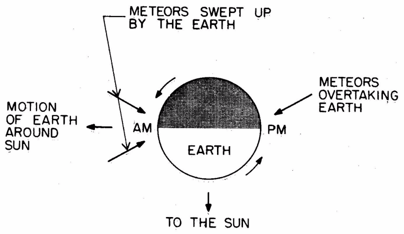


FIGURE 8.4. *Diurnal variation of meteor rates.*

In the evening only meteors overtaking the earth are observed. In the morning meteors with orbital directions opposite to that of the earth and the slower ones with the same orbital direction are observed. (After G. R. Sugar, 1964, Radio propagation by reflection from meteor trails, Proc. IEEE 52, No. 2, 116.)

Figure 7 - yearly and daily variation

The typical meteor ionizes at about 80-120 km (50-75 mi.), about the same as the E layer, so MS distances are about the same - 800-2250 km (500-1400 miles). It was expected that the Leonids, being our highest-velocity shower, would ionize higher and thus enable longer than normal distance contacts. In fact, during the 1998 and 1999 Leonids, using Israeli military phased-array radar, Dr. Noah Brosch and his team claimed to find two populations of Leonids. One group ionized at the expected height of approximately 120 km. But the other group ionized at twice that height! His paper appeared in a recent edition of the journal, *Earth, Moon and Planets*. Unfortunately, it doesn't shed much light on what was observed. Those familiar with meteor radar astronomy comment that the second peak was most likely caused by "range doubling" of the radar or by spurious lobes from the phased-array antennas. Dr. Brosch strongly denies these suggestions; but, because the radar systems used were Israeli military radars, he has not been allowed to give any information on them or their operation. Dr. Brosch specifically requested any information that we Amateurs had on extra-long-distance propagation during the shower peaks. There were no reports of any long-distant contacts or reception.

Meteor showers provide an interesting, concentrated period of operation and the opportunity to use SSB. But the overdense bursts of the few major showers really provide very little opportunity for contacts when compared with the daily influx of sporadic meteors. Even though the duration of these pings is usually very short, the number of tiny pings available on many mornings may surprise you. It has been estimated that if you have a 2% chance of completing a contact on SSB, you have at least a 95% chance on HSMS. Of the approximately 215 completed HSCW contacts between W8WN and KOØU/KØXP, no more than 10 contacts could have been accomplished on SSB. Nearly all of those would have been during showers, when SSB MS comes into its own.

Meteor scatter (using any mode) is difficult at distances shorter than about 500 miles (800 km) or greater than about 1300 miles (2100 km) due to the height of the meteor trails, antenna characteristics, the scattering mechanism, etc. (For a good background, the book D. W. R. McKinley, *Meteor Science and Engineering*, McGraw-Hill, 1961, is one of the best. Long out of print, it can sometimes be found in an engineering library or on a used book Web site). For communication at distances under 500 miles, back- or side-scatter or elevated antenna headings are usually needed. At distances beyond about 1350 miles, a good location and high power are necessary. While difficult, both are possible during showers. (Cf. the text files by OH5MS, available at ***http://www.sci.fi/~oh5iy/***).

Because HSMS relies entirely on the tiny amount of scattered signal from underdense meteor trains, the typical sporadic "ping" will be weak and very short. In contrast, the intense ionization of an overdense burst is much more efficient at refracting a VHF signal. However, as noted previously, these overdense bursts are rare and cannot be counted on except possibly during the peak of a major shower, especially on 144 MHz and higher. Greater output power is more important for utilization of the underdense pings than it is for the overdense bursts because of the nature of the scattering mechanism. And, in spite of comments about being too sharp, EME-capable antennas have proved to be better than small arrays for HSMS, primarily because of the extra signal strength. (On the other hand, a lower-gain antenna with a broader pattern may be more effective when relying on overdense bursts, due to the very small number of bursts, but much stronger signals).

Does this mean that a small station cannot use sporadic underdense pings? In order to see what could be done, arrangements were made with our daughter, WD8KVD, to operate HSCW portable from her home near Duluth, Minnesota during a visit in July 1999. An IC-706 MkII drove a 120-watt amplifier, and an 11-element KLM Yagi was mounted on a telescoping paint pole with a maximum height of about 20 feet (6 meters). The location was only fair for VHF. A used laptop computer ran either the Windows or DOS version of *MSDSP* (this was before *WSJT* was available). The purpose was to see how difficult this type of operation would be, and also to provide a new grid (EN46) for other operators. A number of fellows were able to add a new grid to their logs. One morning was spent parked beside the road on a nearby hilltop. Even though the location was much better, the meteors did not cooperate, and only one contact was made that day. However, many mosquitoes (the state bird of Minnesota) had an extra meal.

Portable HSCW operation (indoors only) was repeated at Christmas, 1999, from our son's home near Clio, Michigan (EN83). Using the same equipment but with very flat terrain, contacts between 500 and 1000 miles were easily accomplished. (Details, with a number of photos from both operations, are available at ***http://www.qsl.net/w8wn/hscw/papers.html*** then look near the bottom for the proper pages). Since then, K9KNW/MM has completed a number HSCW contacts from his boat. **W1LP/MM**, operating from the S/S Marine Chemist, has put approximately 50 Gulf of Mexico grids on the air, plus grids down to the Panama Canal and up the West Coast to San Francisco. Some of the Florida high-speed meteor scatter stations (as well as several others farther inland) have been able to pick up so many new all-water grids that it has been jokingly suggested that a new certificate be instituted - the **WAG** (Worked All Gulf) certificate. WZ8D has made several lengthy trips, operating FSK441 while mobile on the US and Canadian highways! FSK441 MS contacts have been just as easy to make with John as with a fixed station. I don't feel that I can recommend this type of operation, for John is also the driver. But he has been doing it successfully.

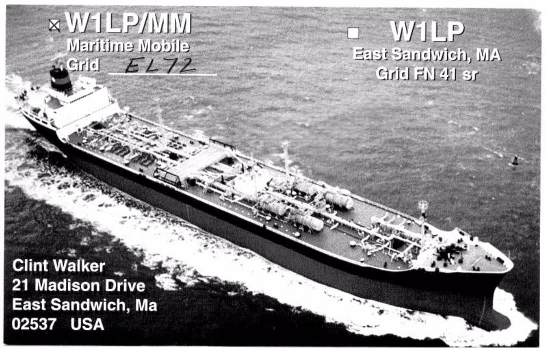


Figure 8 - W1LP/MM, S/S Marine Chemist

How fast does it run?

MS speeds originally were 25-35 wpm (which are still the standard speeds for slow CW MS operation). A number of the early operators could operate at 50 wpm or more, copying in their heads. SSB brought slightly higher speeds to nearly everyone, but with the added requirement of needing to be exactly on frequency to be readable. When the Europeans developed HSCW, routine speeds increased to 1500-2500 lpm (300-500 wpm). North American HSCW started at 1500 lpm and quickly went to 4000 lpm (800 wpm). *WinMSDSP* is capable of speeds up to 20,000 lpm (4000 wpm). While experimental contacts have been made at speeds up to 18,600 lpm using the DOS version, the normal HSCW limit using *WinMSDSP* seems to be about 12,000 lpm (2400 wpm). Using unmodified SSB transmitters and receivers with their standard SSB filters and keying by injecting a keyed audio tone into the mike or data port, speeds up to 10,000 lpm have proved to be no more difficult than the slower speeds. However, at still higher HSCW speeds, several problems arise. First, the signal-to-noise ratio becomes poorer, making very weak pings unusable. Second, the keying begins to sound "soft" and difficult to copy. Using a 2000-Hz injection tone and receiving with a 1500-Hz tone, a dit may not even get a full cycle. Speeds faster than 10,000 lpm are definitely possible, but the QSO efficiency drops - and this defeats the main purpose of HSMS.

Using FSK441, the speed is 8820 lpm (1764 wpm). This speed is fixed because of the audio frequencies used, baud rate, and other characteristics of FSK441. So, while a little slower than some North American HSCW operation, it's S/N ratio is slightly better. This makes it just about equal with HSCW in the 8000-10,000 lpm speeds, and much better than slower HSCW. There is no comparison with SSB.

The equipment needed for HSMS operation is the same as is found in a typical VHF DXer's shack; a multi-mode transceiver, amplifier, horizontal beam antenna, and computer running Windows 95 or higher. If you can work out well on aurora, tropo, and other weak-signal modes of propagation, you should be able to do well on HSMS. For distances greater than about 1250 miles (2000 km), a good location and high antenna are needed. However, for distances under 800 miles, the optimum take-off angle begins to rise. Thus, a low antenna (in the clear) is quite usable for medium distances of 600-1200 miles (960-1900 km). No modifications are needed to a standard SSB rig. Keying is done by an injected audio tone (as is done with many of the digital modes), and standard SSB filters work fine. The emission type for HSCW is designated J2A, and for FSK441 the emission type is J1D. When using HSCW, this method produces keying that is indistinguishable from on/off keying of the main carrier, and is the same method that has been used by many rigs to produce CW. (For a discussion of keying methods, see ***The FCC Rule Book***, Richard K. Palm, K1CE, ed., 1989 edition, p. 8-2). Using standard SSB filters, the bandwidth of an HSCW or FSK441 signal is about the same as that of a voice transmission. The computer-to-rig interfaces are the same as needed for most of the many digital modes. Several different types can be found in the *WSJT* and *WinMSDSP Manuals*, the *WinMSDSP FAQ*, and a number of other papers and Web sites. Or, you can purchase the "Rig Blaster" interface or the MFJ clone. For more technical information, see the numerous papers on the W8WN and other HSMS Web sites.

As with SSB MS, accurate time keeping is necessary. A number of programs are available to synchronize the computer's clock with an atomic standard, but the current favorite is *Dimension 4*, available free from ***http://www.thinkman.com/dimension4***. For MS operation, synchronization within ±1 second is adequate. (All schedules are made using Universal Time).

Other bands

Most of the previous discussion has been concerned with only 144 MHz. Little HSMS operation in North America has been done on the other VHF bands, for several reasons. First, most MS activity has always been on 144 MHz. And second, on the other bands it's either difficult or not really needed.

50 MHz - Pings tend to be weaker but longer, while the number of pings is somewhat greater than on 144 MHz. The lower gain antennas and lower power typically used on 6 meters are apparently the reason for the weaker signals. On 6 meters, pings average about 1 second in length with an occasional ping lasting up to 5 seconds or longer. This is why SSB MS is possible many mornings on 6 meters by well-equipped stations. Also, with E_s, F_2, tropo, and other modes of propagation available, grids can eventually be worked using these other modes. But 50 MHz FSK441 operation has been increasing rapidly in recent months and is a method of easily increasing your states-worked total.

222 MHz - (no random operating yet; schedules only) - As the frequency increases, so does the difficulty. On 222, bursts can be strong but are fewer in number than on 144 MHz. Little HSMS operation has been done on this band until recently. In fact, the first known HSCW MS contact was made on May 2 last year between N7STU and NØKQY. The next day a second 222 contact was completed, this time between N7STU and KØGU. N7STU was running 450 watts to a 7 wavelength Yagi, while KØGU had only 25 watts to a 22-element Yagi! Activity on 222 then dropped off, but has seen a sudden surge of activity in the early part of this year.

432 MHz - (no random operating; schedules only) - This band is more difficult, of course, though possible. Most 432 MS activity has taken place in Europe (the SM3AKW - UA9FAD contact, at a reported distance of 2141 km, is believed to be the world 432 MS record; the North American record is held by N6RMJ and W7XU at 2036 km). Using large antennas and high power, the Europeans reportedly have been rather successful. Pings are few, as expected, and usually short and weak. However, a number of European operators say that they have been surprised by the length and strength of some of the bursts. Schedules are typically one or two hours during showers. The Europeans suggest that you should take advantage of elevating your antenna so that much of the ground noise is in the first null of your antenna pattern. Also, the notes about antenna aiming and using the "hot spot" should be considered because of the much narrower beamwidth of 70 cm long Yagis. (Note that if *WSJT* and its associated files are updated regularly and set up properly, the location, heading, and "hot spot" heading for sporadics [not shower] for the other station are right there on the screen for you. To learn more about using the "hot spot," see OH5IY's papers). As this paper is being prepared, several stations have just reported 432 FSK441 contacts made using daily sporadics. Watch for more activity on this band.

Higher frequencies - These bands are generally considered to be unlikely candidates for MS operation, although 902 MHz should be possible by well equipped stations during major showers. Who will make the first MS contact on this band?

Using HSMS

What can you expect? This depends upon your location, equipment, distance to the other station, his equipment, the time of year, the time of day, and maybe what your dog had for breakfast. For two smaller to medium size 144 MHz stations at a proper distance, you may get only a few pings during a 30-minute morning schedule, or as many as 4 or 5 pings per minute. Conditions can vary greatly month to month, day to day, and even minute to minute.

Does well it work? The Europeans knock our socks off with the number of MS contacts they routinely make, because they run primarily HSMS (except during the peaks of major showers, when SSB comes into its own), while North America is stuck with SSB (if there is any operation at all). Also, Europe has **many** more stations on HSMS (and on VHF DX generally) than there are in North America. The biggest disadvantage to HSMS in the Western Hemisphere is the same as with the other weak-signal modes - the "white noise" syndrome. There just are not enough stations on the band for many contacts.

Things to watch for

Once you start running schedules on HSMS, you may immediately notice some things that you had previously wondered about (assuming, of course, that you have been active on MS and other weak-signal DX work previously).

The first is how radically the number of pings varies month by month, day by day, and even minute by minute. The best time of year for sporadic meteors is the July-January period, with February-May being the poorest. Using HSMS means that it is possible to complete contacts almost any day of the year, though certain periods may be easier than others. The number of sporadic meteors reaches a maximum around 6 a.m. local time because the morning side of the earth is facing toward the direction of its orbital travel, thus sweeping up even slow meteors. Around 6 p.m. local time your location is now on the trailing side, so only those meteors fast enough to overtake the earth will be captured. Thus, MS is much easier in the morning due to the larger number of meteors entering the atmosphere. The exception to this may be during a meteor shower. However, do not bother attempting to use shower meteors when the shower's radiant is still below your horizon. And remember, too, that there are also several daylight showers - some listings are found in the meteor shower table and also linked from the HSMS *Hot News* Web page at ***http://www.qsl.net/w8wn/hscw/papers/hot_news. html***.

If you have operated MS during one of the large peaks of a major shower, you could hardly keep from noticing that even strong, long-duration signals were sometimes difficult to copy, especially on 144.200 SSB. The strengths appeared to vary greatly, and stations would seem to be vying for your receiver's attention, almost as in the "capture" of an FM signal. This is caused by several different phenomena and is seldom seen on an underdense ping, but is common on overdense bursts - see the various references for more information.

Other interesting things to watch for are Doppler shift, doubles, ionospheric scatter, and - who knows? Doppler shift is not often observed on these tiny underdense pings. However, if you get Doppler on one ping during a schedule, you are more likely to have Doppler on another ping or two. (Why?) Another phenomenon you may notice is that on some days (especially during certain showers) the pings may seem to occasionally come in pairs. At first glance, this would appear to mean that some meteors are traveling together, separated by a second or so. Meteor scientists have long contended that this is only a statistical fluke. However, Hams have noticed it for many years, and visual observers have recently been reporting it. The jury may still be out on this question. (It will be interesting to see what ideas the dust-trail Leonid predictions of Asher and McNaught eventually bring to this idea). Finally, when two EME-class stations have had HSCW schedules, traces of ionospheric scatter have been reported on a number of occasions. So when you're doing this type of operating, remember to be alert for more than just completing a contact or working a new grid. HSMS is much easier than other types of MS operation; also, *MSDSP* has the advantage of visually displaying the pings, so you can more easily carry out other observations. Both *MSDSP* and *WSJT* give you the ability to save particularly interesting pings for later study. (If it all becomes too easy and you want a real challenge, see Maj. O. R. Disaster's collection of the works of that great wireless pioneer, Owa Taboo Byam at ***http://www.qsl.net/w8wn/hscw/papers/ lose-qso.html***). Note - while many of you are probably all too familiar with his works, try saying his name quickly if he's unfamiliar to you.

And finally....

If you are serious about VHF DX, you almost certainly have a multi-mode rig with an amplifier, a decent antenna, and a computer. Don't let the "CW" in the HSCW MS scare you away, for you can slow the received signal down to any reasonable speed. And FSK441 using *WSJT* does not require copying CW at all. Try HSMS - you may be surprised.

Necessary reading and resources

So much is available, especially on the Web, that this can be only a place to begin. Note that for HSMS, there is not very much overlap on the Web sites; instead, each tends to concentrate primarily on certain aspects. The HSMS Web sites all attempt to be interlinked; if you don't find what you need on one, look for the Link or URL section and try another site. But to do the most effective operation with MS (or FAI, aurora, E_s, or any other mode), you really need to know as much about it as possible. For all modes of VHF propagation, start with *Beyond Line of Sight*. For meteor scatter, in addition to the above, download OH5IY's papers and the papers on the W8WN Web site.

BOOKS

Emil Pocock, W3EP, ed., *Beyond Line of Sight*, ARRL, 1992. A <u>necessary</u> book for the VHF DXer, containing reprints of all of the major propagation articles over the years. May not be in print much longer. Nothing on modern HSCW, however.

Ian White, G3SEK, ed., *The VHF/UHF DX Book*, RSGB. Nothing on modern HSCW, however.

D. W. R. McKinley, *Meteor Science and Engineering*, McGraw-Hill, 1961. Long out of print, sometimes available in used book stores or on the Web.

WEB

http://www.meteorscatter.net/ The "*Make More Miles on VHF*" Website of Bernie, DK3XT/AB7IY, is probably the best all-around VHF DX Web site on line. If you don't find it there, he will have a link to it.

http://www.nitehawk.com/rasmit/ws1_15.html
Rein's Web site has the largest HSCW section, and is the primary HSCW site for the world.

http://www.qsl.net/w8wn/hscw/hscw.html The HSMS section of my Web site. Many pages, many layers deep, not well organized. Has papers on <u>many</u> specific MS and HSMS topics, but you may have to search some to find them. Watch the ***Hot News Page*** for announcements, etc.

http://www.sci.fi/~oh5iy/ OH5IY's site, with great information on the history and theory of MS operation, plus several programs for MS.
(For still more on governmental and commercial use of meteor scatter, go to the Google search engine and look at some of the links under Meteor Burst Communication).

http://pulsar.princeton.edu/~joe/ K1JT K1JT's Web site for downloading WSJT. (URL is case sensitive). Note - before upgrading to a newer version of WSJT, be sure to delete the WSJT.INI file, or problems can occur when you run the newer version. See the *WSJT Manual* and W8WN's *WSJT FAQ* for more details.

http://www.pingjockey.net/cgi-bin/pingtalk and **http://dxworld.com/hsms.html** Two Web sites for on-line skeds.

And follow the links and URL lists on these Web sites to many more.

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