Meteors & Communication   by OH5IY (C)

CONTENTS

There are three .GIF images supplied (BEAM.GIF, HOT-SPOT.GIF and DOP.GIF) you may wish to see while reading this document.

FOREWORD.

This second file contains mainly background information on matters related to meteor phenomena and how to get most out of the software, by understanding how the output data is produced and what it means. I hope you find this interesting and perhaps even educating.

1. THE SOFTWARE AND METEOR-SCATTER PROPAGATION.

The software is intended primarily to assist and optimise meteor-scatter communication. It does have some use in other radio related MS work. Parallel version called Compact VM-Soft is available for visual meteor work.

Limitations:

The math used is mostly based on research papers on low band-VHF MS propagation and since little research is done above 100 MHz, these models may not be perfect for 144 MHz. The formulas implemented are usable for mid to long distance mid path VHF forward scatter systems.
Since non-VHF frequencies and exotic back scatter and short distance paths are not frequently used for ham radio MS, they are not modelled (properly).

WHAT IS METEOR SCATTER?
(Abbreviated as MS in Europe, M/S in North America)

Radio Amateurs discovered this radio wave propagation mode.
This happened before 1925, by Heising, Eckersley, Appleton and Shaffner.
Were they Ham-Radio operators? I guess everyone in the early days of radio could have been categorised, as Radio Amateurs.

These pioneers observed a new unknown phenomena of "great masses of electrons tossed into the atmosphere rather quickly"(Lovell). In 1931 Skellett proposed meteors being the cause, although making his electron density estimates based on a faulty theory by Maris.

First echoes from meteors of a meteor shower were obtained by Schaffner and Goodall during 1931 Leonids by a 1.6 to 6.4 MHz pulsed radar. In 1932 Appleton, Naismith and

Ingram ran receiving tests using forward
scatter to HF signal skip zone. A year before Beverage, Peterson and Hansell noticed intermittent signals being received on 40 MHz at great distances.
In 1933 Jones received bursts from 200 miles away on 36 to 100 MHz frequency range. In 1942-1944 FCC Engineering Department ran more tests on 42 to 84 MHz range up to 340 miles distance.
Correlation with visual meteors was confirmed in Jodrell-Bank tests.

WW2 pushed radio techniques towards the use of higher frequencies and more power, thus getting rid of those F- and E-layer propagation problems in meteor work. Later test were done also using 2 m wavelength, where "very few meteor reflections were observed"!

Several companies and agencies today are using meteor scatter to communicate to remote sites and mobile units.

Not so many scientists are funded to do research work in meteor astronomy. However the upcoming Leonids meteor storm has raised considerable attention amongst the professionals and this will bring more money to meteor research.

Presently, only a few radar set-ups for studying this phenomena are used. A new meteor radar costs $80.000. Unfortunately their operation is intermittent due to high cost involved. A handful of non-professionals (mostly radio amateurs) within, or outside organisations, with or without connection to research institutes and agencies, are doing systematical meteor data gathering using their own receiving systems. While this may sound adequate, the amazing difficulties involved with this work seem to have it's effect in making the statistical quality of the data often quite appalling.

To summarise what happened in the past decades; the meteor (scatter) (phenomena) was intensively studied in the 1950's. Forgotten in the 60's with satellite communication break through. Re-discovered in 80's, as a reliable low throughput data link for the military and commercial traffic, with the availability of computer technology to control the network.

MS enables radio communication on frequencies up to 500 MHz, at distances up to 2200 km away, by back, or forward scatter mode.
Scattering of radio signals occur (re-radiation, or reflection) at altitudes of 70 to 115 km from ionised meteor trails and heads.

The best compromise in frequency is about 45 MHz for MS link.

The ionised trails and the ionisation cones reflecting the radio energy, are produced by small METEOROID particles hitting Earth's upper atmosphere at cosmic speeds causing the visible phenomena we call METEORS.
Friction of the air molecules, causes the kinetic energy of the particle, to convert mostly into heat energy and produce light and ionisation.

Meteors are divided in to two classes:

Sporadic meteors.
Shower meteors.

Meteor trails are divided in to two main classes:

Overdense trails.
Underdense trails.

Main difference is:

RF energy does not penetrate in to an overdense trail, but does so in case of underdense trail.

The meteoric particles are leftovers from the formation of our solar system originally released by the comets and asteroids orbiting the Sun.
The size of these particles is mostly small, like a grain. Extremely small dust particles are being blown out of the solar system by solar wind.
On the other hand some dust has been observed being blown into our solar system from nearby A-class stars at speeds in excess of 100 km/seconds.

A coin sized meteoroid would cause a fireball in the sky and a long radio reflection. They say a 1000 m rock could kill all life on Earth indirectly.
A particle that survives through the atmosphere and falls on the ground is called a METEORITE, sometimes causing a meteor crater to form.

The name originates from the earlier classification of this phenomena to the same category with other (aerial) meteorological phenomena, like lightning etc., before the mid 18'th century, when the true reason was suggested and later proven and accepted. It is also often know by the name "shooting stars", a misleading name that should not be used. Stars are huge compared to meteors and they produce their own light from nuclear reactions.

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    Diagram showing the effect of distance to communication reliability.
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             1000 km                1500 km                2000 km

                              Distance between stations
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A complete Amateur Radio MS test on CW consists of some 15 characters exchanged successfully during one hour by two stations.

The data for the curve above is from 100 of my 144 MHz CW MS test between

1985 and 1992. The equipment used were 4*14el/17 dBd up to 4*15el/19 dBd
7.5 m boom antennas and 100 W to 1000 W TX output power.
RX NF varied from 2 dB to 0.7 dB.
Some of the tests were during major showers.
Time of the day and the equipment at the other end varied.

This shows the ideal distance is near 1400 km. At 2200 km the success rate is reduced down to 3%. Below 700 km the rate drops below 50%, caused by the shortening of the reflections and increase in back side high elevation reflections.

Side scatter path, or smaller antennas should be used for such short distances.

On short distances, if an obstacle prevents forward scatter, back scatter can be a way to success. The better polarisation choice could be vertical, but it does not work for forward scatter paths under 600 km. On long distances horizontal polarisation is close to ideal.

Lower transmitting power would cause the curve to retain it shape, but be much lower. Smaller antenna would drop the long distance success rate. At location with mountains blocking the propagation path, the curve would have a deep downward trend from the point where path elevation is equal to the obstruction induced minimum take-off elevation.

The data transfer rate must be high because of the short duration of reflections. Usually 500 to 10000 baud's are used.

Radio Amateurs use intermittent CW with Morse code, or SSB phone modes to communicate, with simplex and 15 second to 5 minute transmit periods. Commercial meteor scatter links, for meteorological and environmental data collection, use fully automated networks, with PSK, or FFSK modulation, polling, duplex, short periods like 40 ms and 2 to 10 kbps data rates. Several such systems are in use in many countries, like the AMBCS in Alaska, SNOTEL (40.925 41.650) in the US and other similar systems in Canada, UK and Italy (see: MCC homepage).

FOR WHAT DO YOU NEED A COMPUTER?

Yes you do need a radio and not necessarily a computer, but it helps a lot to have one connected to your transceiver.

With the PC you can optimise the time of schedules.
Part of this process is to calculate the geometry for the shower and having some knowledge when a shower is active. If the geometry is not favourable, or the shower is below horizon, this particular shower will not be of any help. Still there are always some sporadic meteors, or other showers available. Maybe the best advantage, is the ability to key the transmitter with PC and let it handle the sequencing, while you concentrate on the receiving.

THREE WAYS TO RECEIVE HIGH SPEED CW

A. The old way; tape recorder
For receiving high speed CW meteor reflections, you can use a variable speed tape recorder, with at least 10/1 speed ratio and preferably an audio up-converter. The up-converter is used during recording, to convert

the 0.3 ... 2.4 kHz RX audio, up to around 6 kHz, so when you play it back at low speed, the audio pitch is reduced back down to 600 Hz.
The up-converter is simple; Just a TBA-120 IC and a handful of passive components around it. Described in the British VHF DX Handbook. Original schematic is on Motorola's Linear Integrated Circuits, 1980, p.6-86ff that uses MC1496 or MC1596. Contact DF4LY for PCBs and units.

B. New and efficient; DTR+

A new way is the DTR-MS by DF7KF. This agile and handy RAM based CPU controlled digital sound storage/playback unit can reduce the speed down to ratio of 1/50 making the 5000 LPM readable and opening a new range of speed available for MS. It works with 12 Volts DC, includes a low loss audio up-conversion software and is ideal for portable use. Preliminary test indicate some 10% (1/10) increase in completed schedules using DTR. The price is around 490 DM. New DTR+ version has built in AF-keying and automatic REC start. Contact Dithmar Daude, DF7KF for more information.

C. Using PC.

Same kind of audio storage/playback can be done with computer memory.

DL3JIN has a DOS application for SoundBlaster sound card. It does not require an interface, but is an early version and in time may become as handy to use as DTR is. The playback sounded reasonably good.
You find the zip file from http://www.ilk.de/sites/gap/soft.htm

9A4GL has CW MS software for PC and sound card at
http://fly.cc.fer.hr/~9a4gl

2. ABOUT PEAK CALCULATION

Information of the shower peak time is equally important, as the geometric trail efficiency, but peak times are often so hard to predict!

You might be experienced in electronics, where most of units like frequency, resistance etc. are expressed with 3 to 7 digits, or with 1% uncertainty, or ppms. It is fully different thing with meteors. For instance the maximum of the Quadrantids "can" be predicted with +-3 hour uncertainty, but this has not always been the case. Then, if we talk about some minor showers, different radiant catalogues show +-2 day scattering for the maximum date on several cases. You must not expect any 7 digit, or 0.1 ppm type of accuracy in Meteor Astronomy, or in the predictions and data shown by the software, purely because of the nature of meteor phenomena! Meteor Astronomy is not an "exact" science in this sense. Random fluctuations in meteor density may be severe.

Shower predictability is based on observations from previous years.
On her orbit around the Sun, the Earth crosses every year at the same Solar Longitude a meteor stream produced by parent comet on it's own orbit.
We call this crossing event a meteor shower.

When a comet approaches perihelion, the Sun starts to heat it up after it gets inside Jupiter's orbit and it begins to eject matter and gases. In time, loop formation scatters the particles along the whole loop (orbit) and the shower peak becomes less intense, but an annual shower. The flux tube spreads out for many reasons causing shower duration to extend, but become less spectacular. This process occurs mostly in the perihelion, where the stream is most dense and the particles collide.

Solar wind and other phenomena gradually de-orbit smaller dust particles. Smaller particles orbit on the inner edge of the loop, larger ones on the outer edge, if it is an old stream. The size of particles to be encounter first, depends on whether the stream is on it's way towards perihelion (descending node), or going to aphelion (ascending node; Arietids). This reverses the shower activity and population index (r) profiles. (Presuming the orbital direction is the same as with planes).

Things are not always that simple. The loop often consists of matter being ejected on several different orbits and since the comets suffer from orbital transitions, the stream structure is more complex than I previously assumed. Comets and more importantly, meteor stream orbits are not stabile and also can be perturbed by the gravity field of Jupiter, the big celestial "vacuum cleaner".

The peak calculator does not compute orbital nodal changes or other orbit perturbations, making peak calculations imprecise for years far from present. These nodal changes will cause the Quadrantids to stop colliding with the Earth in approximately 100 years.

The ZHR of 2 is the lowest value for a stream to be called a shower, since visual observations can not reliably detect activity at lower level. Below ZHR 2 they are classified as sporadic. Average HR (hourly rate of visual meteors) for sporadic meteors is in the 6...16 range (average 10).

The 87 MHz raw data provides by no means a global view into the reflections provided by the shower(s). It is a local view for the specific path with it's limitations in observatility and lack of geometric correction. On the other hand, since you make meteor scatter contacts, there is no reason to make observatility corrections! The curve shows you how the number of reflections has varied. It is not an activity profile for scientific analysis on stream's spatial particle density.

When looking at the 87 MHz reflection data curves, you have noticed some showers have sharp peaks and others broad, lasting several days. (A single hour long peak is usually caused by a fireball, or two. They will not re-occur next year.) Several showers have more than one peak, like the Orionids. A periodically active shower may not appear at all one year, or might have peak time many hours, or even days, before, or after, the predicted time. The cause for this was explained earlier. Those factors makes it impossible to predict with a minute, or even hour accuracy, the peak time of any shower.

The amount of meteors we will encounter, is even a bigger problem than the time of the peak. "Meteor showers have an inherent unpredictability resulting from our lack of knowledge, regarding the dust distribution about the parent comet!" (Peter Brown, UWO). The is NO way to remotely detect these widely spaced tiny particles travelling in space tens-, or hundreds of millions kilometers from us. Not before they hit a satellite, or atmosphere.

When a near comet type of meteor outburst like the Perseids 1991... appears, the Solar Longitude co-ordinate (time) of the new super maximum is NOT stable! The peak calculator can not handle these events and you should NOT rely on the peak calculators results, when Leonids will produce the long awaited meteor STORM in 1998. There are several solar longitude values available for the Leonids peak for 1998, we just do not know the correct solar longitude until after the event (http://www-space.max.arc.gov/~leonid).

Solar activity induces variations on the observed ZHRs from year to year. Lowest rates occur during solar cycle maximum. Major auroral events have been observed to reduce meteor radar rates up to 30%. These changes have nothing to do with the number and mass of the particles of a stream hitting the earth, but are caused by warming and expanding atmosphere and lower air pressure gradient at meteor layer heights.

Different maximums

There are several kind of maximums. You might have heard of visual maximum, radio (radar) maximum, photographic maximum and telescopic maximum. The differences in the maximums are caused by the differences in the sensitivity to observe faint meteors with a particular method.

This effect is not so obvious on all streams!

The radar systems used can detect meteors down to visual magnitude +9...+13. These radars operate in Japan and New Zealand on 27 MHz and in Ondrehov on 37 MHz, so there is a big difference to 144 MHz reflections.
On 144 MHz you can not see those faint meteors and the detection sensitivity could be worse than the one achieved using visual method.
The term "radio maximum" does not cover ALL radio systems, since it is frequency and system dependant!

The time difference between so called "radio maximum" and visual maximum depends, if the particles have been dispersed and the particle size distribution in the stream is un-homogenous. The Quadrantids stream is one of those where the "radar" and visual maxima are separated on average by some 6 hours. On the 87 MHz forward scatter I use to measure the reflections, the difference seems to be only 1 to 3 hours. This sets the limiting magnitude to somewhere around +6.5 to +7. If frequency increases, the limiting magnitude gets lower.

This raises the question, is the Peak Calculator useful?
This depends up on your expertise:
If you have no idea, when a shower peaks, make a guess with the computer!

Do not forget: The software does not predict the maxima, the parameter file is the key to success! It is up to you to keep it up to date!

3. VARIOUS METEOR SHOWER RELATED COMMENTS

Meteor showers can be classified in three main categories:

Annual showers

Periodic showers

Lost showers

Annual showers produce consistent amount of meteors each year at least for decades.

Periodic showers produce none - to low activity normally, but at certain intervals they produce high rates, or even meteor storms.
ZHR rate used, or indicated in the software is the normal rate.

A ZHR marked as >10 means the shower normally produces about 10 meteors per hour at peak, but during an outburst, significantly more (ZHR >20).

Lost showers are lost and not used in the software.

One of the most intriguing features of the meteor phenomena, are the meteor outbursts. Dr. P. Jenniskens defines an outburst as an event, where meteor activity of a shower exceeds by at least 2 times the normal annual activity. Some of these outbursts are caused by excessive amount of material on a section of the meteor stream.

New ejected matter is observed near the parent comet. In time it will spread out. When the comet is near perihelion and if Earth passes through the stream, this may cause an outburst. Streams passing farther than 0.1 AU (15 000 000 km) will not cause a meteor shower. The shorter the distance between the nodes of the comet and the Earth, the more intense is the outburst. Such an event is called a "near-comet" outburst.
Common to these outbursts are not only the clear increase of ZHR, but also the peak solar longitude behaves almost unpredictably; It will not shift +6 hours/year, or appear at the time of the peak in the years before the outburst!

The other type of outburst is the "far-comet" outburst.
The cause of this phenomena is mostly unresolved. However P. Jenniskens links the 10..14 year interval to the wobbling motion of solar systems centre of mass influenced by Jupiter and Saturn and that in turn bringing the stream in to a collision course with Earth time to time.

At least a few outbursts of unknown type occur in every ten years.
Their reasons are unknown, some have been unique events not related to any showers, nor linked to any comets, or asteroids.

If you wish to know all the latest discoveries on meteor showers, see Dr. P. Jenniskens papers on Astronomy and Astrophysics: "Meteor Stream Activity". Parts 1, 2, 3, 4, 5. and his papers in Astrophysical Journal and Meteorics and Planetary Sciences. Not recommended for the beginners although.

Quadrantids, the short duration shower has been producing enhanced rates increasing the ZHR from the nominal 120 up to 180 every 5 years (next time year 2002). This does not put this shower in to the group of outbursters, but is a feature certainly worth while to remember.

Activity of the Perseids first peak has been reducing, but in 1997 it was still fairly pronounced (ZHR 155) with bright meteors. The peak provides long reflections. It drifts by about 1 hour / year closer to the old peak occurring several hours later. Reappearance of the P/Swift-Tuttle comet in 1992, origin of this shower, caused this near comet outburst.
It's period is 135 years. Too high expectations in 1993 and even more 1994 caused disappointments as the activity did not reach storm levels.
Some models predict the activity might start to increase in the coming years.
See the WGN, Oct 1996, IMO's Global analysis on Perseids stream activity from 1988 to 1996 for more information (shift + 0.05 degrees/year).

Pi Puppids are caused by comet Giacobini-Zinner (1946 V).

Arietids are linked with asteroid Icarus 1566.
There must be something wrong with the ZHRs/maximum solar longitudes of the Arietids and/or zeta-Perseids shower. It seems the MS radio data

activity profile consistently differs from the computations based on
IMO Meteor Shower Calendar's parameters. Wait for further updates.

Draconids (Giacobinids) sometimes (1998!?) produce short lived meteor storms. In 1985 ZHR peaked over 1000! This short duration shower is on 9/10 October.

Orionids and Eta-Aquarids are caused by the famous Halley's comet. It orbits Sun in 76.1 years. I has several peaks. In 1994 there was an outburst on October 18.

Lyrids parent comet is Thatcher 1861 I with a period of 329 years.

Taurids are remnants of comet Encke (1971 II).

Leonids parent comet is Tempel-Tuttle with a 33 year period. It reaches perihelion in 1998, when a real meteor storm is expected. Activity exceeded ZHR 70 in 1994 with many bright meteors seen. Outstanding activity is expected in the coming years, specially in 1998. This situation is not expected to repeat within the next 400 years, so do not miss it!

December Phoenicids are linked to comet Blanpain (1819 V).

Geminids parent is an asteroid 3200 according to IRAS satellite results. This is the most consistent shower. Period is 1.68 years and shower contains dense, rocky material. This shower is the most reliable and produces fairly equal activity each year. Any significant difference in activity would be a big surprise.

Ursids parent comet is P/Tuttle with 13.5 year period. Next perihelion is in 1994. An intense outburst occurred in 1994. The 1995 and 1996 outbursts were not so obvious, but still exceeded outburst limit.

Look out for Draconids and definitely Leonids in 1998 and 1999!

ZHR (Zenithal Hourly Rate) is the rate of meteors seen visually by naked eye in one hour in ideal dark conditions, when the shower radiant is at zenith. It is the most common way to indicate the activity of a shower.

If an observer sees 50 meteors, the ZHR value could then be near 100. The ZHR conversion has correction factors for limit magnitude, obstructions, time, perception, shower population index and radiant elevation.

A question comes up: is ZHR a "fair" way to express activity and to make comparisons. Sorry, it is not. It reveals nothing on the brightness of meteors. Comparing merely ZHRs does not give you the picture, you need at least also the population index. During outbursts there is often an abundance of bright meteors causing outstanding reflections, but do not raise the ZHR considerably. Bright meteors are one the reasons for fantastic long meteor reflections on 144 MHz. Perhaps it would be useful to introduce a new term describing this effect; a Bright Meteor Outburst (BMO), where the number of bright meteors (brighter than mag 0, or what ever) exceeds twice the normal rate for it's class of meteors. Likewise there could be Faint Meteor Outbursts (FMOs) like the Leonids has caused and is expected to cause.

Some showers are difficult to model mathematically to calculate current ZHR profile. Those showers consists of several nearby radiants and maximums.

Such showers are at least Virginids, Orionids, eta Aquarids and some other minor showers.

Many of the May/June daytime showers do not produce activity every year. Omicron Cetids and some others produce variable activity.

4. ABOUT GEOMETRY AND TRAIL EFFICIENCY

MULTIPLE vs. SINGLE SHOWER OPTIMISATION

Showers do overlap and some people would like to compute all active showers for the date. I do not agree, for many reasons.
The target is NOT to calculate number of reflections, but to help you to optimise your scheduled scatter contacts, or provide indication of conditions for the desired moment. Such calculation is possible, but requires a powerful CPU to make the results available fast enough and the presentation could be confusing.

There are only a couple of days (June 5 to 12), when two major showers with high activity appear simultaneously. Luckily the radiant of these showers differ only by some 18 degrees in RA and 1 degree in DE.

To prove such calculating for "all showers" is not worth while, I picked a random date in September. No major showers are active, but several minor showers are there. A proper month for the purpose.

The date is September 10.
The ZHRs calculated with the generic activity model are purely statistical and represent long term averages, not actual ZHRs to be observed.

Showers	ZHR@10th	Available(60øN)
I-Aquarids N	0.1	8 hours
g-Leonids	0.6	17
d-Aurigids	5.4	24
Piscids	2.1	12
k-Aquarids	0.2	12
s-Orionids	0.4	10
Arietids (Oct.)	0.1	11
a-Aurigids	0.2	
k-Cygnids	0.1	
Perseids	0.1	
d-Aquarids N	0.1	
i-Aquarids S	0.1	
a-Capricornids	0.1	
Sextantids	0.2	
Taurids N	0.1	
Taurids N	0.1	
Leonids	0.1	

ALL SHOWERS ARE NOT ABOVE
HORIZON AT THE SAME TIME
AND HAVE THE SAME RADIANT!

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total 10.1

of which
d-Aurigids 6.7 = 53%

adding

```
  Sporadics(avr)    12
 -------------------------------------
  total            22.1

  Sporadic         12   = 54%     <-- Displayed by the software.
  Showers (all)     10.1 = 46%

 -------------------------------------
  d-Aurigids        5.4 = 30%     <-- Used to produce efficiency
                                          curve by the software!
  (2. active)
  Piscids           2.1 =  9%     <-- Do you really think this rest

  (. active)
  g-Aquarids        0.5 =  3%     <-- should be calculated for schedule

  (7 different)
  rest of showers    1.3 =  4%     <-- planning??!!
```

Sporadic meteors dominate outside the major showers! Therefore computing data for showers with ZHRs less than 5, is often futile.
These showers are being masked by sporadic meteors having average HR of about 6 in the evening hours and up to 16 in the morning hours. While these low ZHR showers do provide extra reflections, sporadic meteors are essential in these cases, not the minor showers. I find no reason for schedule optimisation method based on a handful of weak radiants scattered all over the sky! (Weak means: low meteor activity)

If you do not accept this, try it in practise in early March. You have Virginids, but conditions on meteor scatter are appalling since the number of sporadic meteors is low!

SCATTERING GEOMETRY

Optimising geometry is the most common way to select times for scheduled MS activities during major showers.

Since many new users do not seem to know the basics of forward meteor scatter geometry and other necessary aspects, I will make an attempt to express them here, briefly. Now, it would be a good time to have the DOP.GIF on your screen, so you may see the mail trail types and what they look like, or listen to DOP.WAV to hear them!

The key principle as it is found in reference literature:

Since the scattering properties of meteor trails are aspect sensitive,
it becomes necessary for a trail to satisfy specular reflection condition.
Therefore the trail has to be tangential to a prolate spheroid,
whose foci are the two stations.

Several different trails can fulfil this condition. Of those, the preferred trail position is the one giving the shortest propagation path from transmitter to trail to receiver.

This situation can be difficult to understand and visualise, so an explanation may help.

#1 describes the normal case and others some exceptions to it:

1. All type of trails, overdense, underdense and head reflections
should fulfil specular reflection condition, which in the optimal case means they
have to be oriented at right angle (90 deg) to the great circle line drawn
from station A to B and at midway between A and B for best RF signal propagation.
Different path orientation together with constantly changing radiant position
may provide anything from ideal, to unusable MS propagation geometry.

Since the A-B path is usually a fixed parameter in the equation,
you should determine the best radiant / path alignment within the
course of the day. The efficiency graph best serves that goal.
A wider approach would be to search for the shower that is ideal
for the desired A-B path (not forgetting differences in their activity and
other shower parameters).

2. Of non-specular trails only overdense ones do provide reflections through trail
distortion, but this usually occurs after a second, or more, when the signal
level has started to fall due to trail diffusion compared to specular
case initial value.

3. Optimum shower radiant elevation is about 45 degrees. Other radiant
elevations either provide worse geometry, or lower trail ionisation.
Worse geometry means the reflections may be out of reach or have higher
scattering angle leading to higher path loss.

4. One may achieve significantly better results with directional
antennas, if the ERP is used effectively to illuminate the
trails appearing in the shower locus, an area, which is a result
of the required condition in 1.

The influence of any particular shower, with meteor trails that intersect the
desired A-B path, will result in enhancement of propagation over
that A-B path that varies from non existent to substantial. The
degree a shower enhances propagation, over sporadic meteors, depends,
primarily, on the spatial density (number), intensity, duration, angle and location
of those intersecting trails relative to the desired A-B path. The geometry
program's graphs provide insight to the phenomena, based on imperfect,
but valuable, statistical data.

An alternative is to illuminate one or both of the sporadic meteor hot spots.
If at a certain time the active shower fulfils the condition explained in 1., then the
shower meteor trails cause reflections within the same area, as
sporadic meteors do (one of the two hot-spots).

The optimum antenna direction (for best reflections to target
grid square) includes both azimuth and elevation. NOTE: At any given time
the shower locus area that gives the best reflections, (predicted by
the program) may not enhance propagation to the desired grid location
if that condition is not close to the desired path/trail geometry
specified in 1. or is below radio horizon for one or both stations.

5. It is NO coincidence, that most sporadic meteor reflections
occur near the A-B path midpoint (hot-spots), because the best
statistical chance (which is the actual cause for the hot-spots
existence) to provide best propagation geometry (lowest path loss
and longest reflection) exists on those meteors trails, which are,
as in 1., at right angle to A-B and occur half way between A-B for
the lowest scattering angle.

6. The previous information is valid for medium to long distance (about >1000 km) midpoint forward scattering systems. For shorter distances the proportion of short duration back reflections increases as the rear side reflections become withing range (end path scattering).
The maximum range for back reflections is much less than forward (<1100km). These back or side scattering modes require their own algorithms and since they are seldom required by in Ham Radio MS, they are not modelled in the software.

Only the geometry and antenna pattern were considered, which is far from the complete solution, as you should have noticed by now. The list of things of importance is long and it is often difficult to weight them correctly. You may find additional information to the subject from the Internet by doing Alta-Vista search on "meteor+scatter" and browsing through the professional links, like http://www.borg.com/~warrend/metburdu.html.

DATA PRODUCED BY THE SOFTWARE ON GEOMETRY

Trail efficiency is a relative indicator of the favourable geometry that produces most reflections. The higher the trail efficiency is, the better. This is especially valid on VHF frequencies (30...300 MHz) using forward scatter. If shower elevation is low, the electron density is low and the reflections get weaker. If the shower elevation is high, the reflections will be strong, but short and few.

To take head type of reflection and the diameter of radiant in account, I have raised the reflection efficiency values for co-aligned path - radiant azimuth and radiant at zenith from 0% to 20%, as 87 MHz data suggests. If frequency dependence can be determined, it will be included on later versions.

The head reflection becomes important on higher frequencies. Lack of related articles keeps me from saying much about the conditions favourable in these cases. The reflection takes place in parabolic, or elliptic cylindrical cone of ionisation around the meteor and is less aspect sensitive and lasts only as long, as the meteor burns. This means usually some 0.1 to 1 second. Until I know better, I just say if the trails are tangential in the illuminated area on 144 MHz back scatter, they will yield head reflections.

Duration (1/e) of low density short wavelength reflections:

t=wl^2/16*pi*D

t time in seconds
D= 1...10 m2/s
wl= wavelength in meters
pi=3.141592

Duration (1/e) of high density short wavelength reflections:

t=2*pi^2*D*R/wl*v^2*q*re

D, pi, wl, t = as above
q= electron line density electrons/m
v= meteor velocity
R= uplink&dowlink path length

re= scattering cross section

The reflection map shows clearly how the best point of reflection behaves. The possible reflections come from a line, or actually a narrow band, called locus of the shower. The locus looks too complex to calculate and takes too much time. Therefore the MS-Soft uses the so called cylindrical model, which provides the same results on long distances as locus modelling, but becomes more inaccurate as distance gets shorter.

Often, when the reflection point marginally goes out of range, part of the locus is still within reach, so the shower does yield reflections from trails also. The path loss is not calculated in those cases and will not be shown. Red colour is used to alert of this condition on the graph and list screens.

I admit this gives a bit pessimistic view on things, but keeping in mind you are optimising the sked time, the presented data will be useful.

What is the difference between path loss and trail efficiency?
Path loss indicates the expected signal level, while trail efficiency indicates the relative scattering efficiency geometry of suitably oriented trails from shower meteors and relative quantity of reflections.

Why is the path loss lower with sporadics, than with a shower?
Sporadic meteor trails appear "somewhat" randomly oriented.
Most of sporadic trails are observed (for geometrical reasons) within the so called hot spots, because they provide favourable reflection geometry. Shower locus is rarely located near that ideal area and thus the path loss is somewhat higher.

Path loss is calculated for the polarisation selected in the set-up file.

T-wait is the time in minutes needed for a 1 second long reflection to occur at 50% confidence. The time is receiving time and must be doubled for 50/50 simplex operating. T-wait of 30 minutes means it takes 60 minutes of operating to get long enough reflection with a 50% confidence.

One second long reflection transfers both calls and a report at 1500 LPM.

T-wait is calculated, when reflection point of the shower is available, to include both sporadic and shower meteors. Otherwise it is calculated and displayed only for sporadic meteors. This makes sharp bends on the T-wait curve.

T-wait is derived from the reflection angle, reflection height, expected number of sporadic meteors, expected number of shower meteors and their velocity, the r-index for the shower, or 3 for sporadic meteors and common scattering area.

CW on-line display shows T-wait for YOU, if the ERP of the other station is available, instead of using your own ERP, as in the Geometry section.

With manual RA/DE and minor showers, T-wait shows only the wait time with sporadic meteors, since ZHR for the shower is not available to calculate T-wait for the shower!

Your own ERP has effect on the T-wait displayed on Geometry screen.

T-wait is a highly experimental statistical index. It suffers from the simplified model of locus calculation (cylindrical model) and should be used primarily for optimising schedule time, not to be treated as accurate value. Using sporadic meteors the model should be fair, but with a shower available, the T-wait can be less accurate. The population index for a shower is used to cause a 10 fold difference per 2.5 magnitude units deviation from 3 in to the formula. It compensates for the change in r-index and it's effects on T-wait. The lower the r, the brighter the meteors are and T-wait becomes shorter.

If you change operating frequency, the number of meteors producing overdense trails changes and the meteor layer height changes a little.
A short comparison: 144 MHz against 50 MHz.
Path loss is some 8 dB lower on 50 MHz. There will be nearly 10 times MORE meteors capable of producing overdense trails than on 144 MHz.

Side scatter can yield better results, if the distance is short, or if vertical beam width of the antenna is narrow, or direct path has obstructions.

I recommend you to select an offset with elevation of 5 to 10 degrees, if possible. Negative elevation gives no reflections! When looking at the numbers, keep in mind the antennas do not produce a laser like beam! Even a shower radiant diameter is 3ø to 15ø.

Generally you should aim for availability of reflection point, high trail efficiency, short T-wait time and low path loss for selecting the schedule time, if there is a major shower active.

Optimising for sporadic meteors?

Sporadic meteors will help you to make a QSO, if you run the sked in the morning hours. More meteors hit the forward facing side of the earth in the morning. Further more, the is a large difference in the speed distribution between evening and morning, the latter being considerably faster. Ratio of counts in the 87 MHz data shows the worst and the best hour ratio of 1/2.5, if only sporadic meteors are available. March is such a month on northern hemisphere.

There are 6 main radiant areas for sporadic meteors: N.Apex, S.Apex, Antihelion, Helion, N.Toroidal and S.Toroidal, these have 16...21 degrees radius. They all have their own annual variation pattern. So far no reliable data is available on the quantitative distribution of sporadics between those sources for enhanced accuracy in modelling sporadic rates.
Some studies suggest that the Antihelion and Helion meteors are actually not sporadic, but remnants of highly diffused low activity radiants along the ecliptic plane. Toroidal radiants consist mainly of faint meteors.
The software calculates and shows (the position of) more active of the two hot spots for you.

You should elevate your antenna, depending on your antenna's vertical beam width, when distance is shorter than 1500 km. Ideal angle is shown on the screen with azimuth.

The ZHR shown on the graphic screen shows the computed ZHR values using an algorithm introduced by P. Jenniskens. The results should be taken, as guidelines, not as an accurate and absolute truth!

SIGNIFICANT variation in peak rates of a meteor shower is the ratio of

1:2, or more deviation from expected!

This is pure statistical math:

if |x-u| <= 1.96sigma, then deviation is not statistically significant.
-
Anything less can be said to be "as expected".

ZHR should be used together with r index and meteor velocity, when comparing reflections from different showers. The population index r, is taken into account by this software only in the T-wait parameter. This should not cause problems in optimising schedules, since you usually do not have a choice whether to use this, or that major shower for the test. If you would have, the one having lowest r, would be of advantage. You may read more on r-index from the books listed at the end of README50.HTM file.

5. MATHEMATICAL MODEL OF METEOR SCATTER

WHAT THINGS HAVE EFFECT ON METEOR SCATTER SIGNAL STRENGTH?

I came up with a list containing 25 factors having some effect:

Radiant elevation.
Radiant azimuth related to path azimuth.
Wind created trail distortion re-orienting long lasting trails.
Frequency (wavelength).
Angle of incidence.
Angle between incident electric vector at the trail and the direction
of the receiver from that point.
Angle between trail axis and the plane of propagation.
Distance to the receiver and transmitter from the reflection.
Refraction of radio signals.
Transmitter power used.
Antenna gains used.
Obstructions.
Atmospheric attenuation.
(Oxygen vapour: 0.7 dB worst case on 144 MHz, usually below 0.1 dB)
Electron radius (constant).
Solar (geomagnetic) activity induced decrease in atmosphere density gradient.
Height dependent diffusion of the trail.
Faraday rotation on lower frequencies with linear polarisation.
Height of the trail.
Trail radius.
Trail length (effective length and height decreases as frequency increases).
Trail electron density, effected by:
- Meteor velocity.
- Meteor mass.
- Meteor mass density (0.2 to 0.3 g/cmý on cometary material,
2 g/cmý on the Geminids meteoroids).
- Meteor shape.
- Angle of impact.
  - Contributing to height of maximum ionisation on the trail.

Only a few of these are constants. A couple of the parameters are known at +-20% accuracy, a couple of them varies a lot and one (or many) that can not be pre-determined at all.
Various combinations of geometry produce different reflection length.

Energy produced at the impact:

E=«mvý

0.005% produces ionisation, 0.1% produces light. The rest of the energy (99.9%) goes into heating the meteoroid in case of fast meteors.
On slow meteors the light production is only 0.01%.

> A 0.1 g particle at 72 km/s burning in 1 second would produce light equal to a 260 W light bulb (presuming 100% bulb efficiency), this phenomena would produce visual magnitude near mag+3.4 for one second. In reality a meteor light curve rises steeply towards the end and the case above would peak at mag-0.3 (at impact angle 45ø).

Meteor velocities vary from 8 to 74 km/s. A high percentage of sporadic meteors come from radiants within 30 degrees of the ecliptic plane, known as the ecliptic distribution.

In case of a meteor shower you have more known parameters. The mass distribution of most showers is known. Sometimes it is hard to predict the actual spatial meteor density, the exact number of meteors/kmý/hour for each year's maximas.

All mentioned above is to show you the problems and at least to me, the complexity of computing meteor scatter link path loss in and out of showers.

What are pings and bursts?

The term "ping" is unknown to meteor scatter professionals and scientists. Neither was it found on any IARU documents (VHF managers Handbooks etc), and there is no common and exact definition for a ping.
If it can be found printed anywhere, I suspect it is only a personal opinion, or based originally on a verbal agreement between some MS operators from past decades.

However, radio amateurs have used this term to describe a short reflection. The European "definition" evolved most likely in the 1970's, when high speed (then <600 LPM) CW gained popularity in Europe. With the less efficient equipment used those days, the shorter reflections were either too short to pass full characters due to slow speed and/or too weak to decode with the equipment available for the purpose at that time. It was no surprise that in 1997 most of the European MS operators still defined the "ping" as a reflection too short, or weak to pass information. In USA this does not seem to be the case and this confirms the above stated definition's was born in only in Europe.

According to my poll the European definition has run in to a dead end, since basis of the definition were no longer there and the subject immediately raised some questions on the logical correctness of this definition. The contradictories derive from the fact, that the used CW speed has increased since 1970's by about 4 times and new digital equipment makes copying useful information from a weak reflection much more easier.

In USA the common opinion seems to be that a ping is a reflection that sounds like the word "ping" as heard from the loudspeaker. There even were a few opinions describing it, as the amateur's way to express an underdense meteor reflection.

Against the common use of term "ping", I use it in this file to describe a meteor reflection from an underdense trail. It is about time to start using a more useful definition for a ping and to produce non-technically biased data on propagation conditions by splitting the received reflections in to two categories, where underdense reflections are called pings and overdense as burst. The most simple way to do this, is to measure the length of the reflection. The threshold is not sharp, but a crude division can be made by calling anything shorter that 2 second long reflection on 50 MHz a ping and longer ones as bursts. The duration depends on used frequency:

t = (300/f)ý / 18

where f is the frequency in MHz (50 MHz) and t is 2 seconds.

A more precise determination could be done by looking which reflections decay exponentially and count them as pings, but for routine ham radio MS contacts this is not feasible.

The old way to determine a ping has become invalid and does have serious lack of logic by definition, while the underdense/overdense division is based on well known and studied physical facts, as described in scientific literature.

Selected parameters used in calculations

For basis of computation, I have taken a meteor having just enough mass to produce an overdense trail, as a standard meteor (reflection). This is because such a reflection is useful in ham radio contacts. The duration of such reflection allows transfer of several characters on phone and on high speed Morse code. Meteor link requiring more dense trails will suffer significantly from reduced data transfer capability. (Meaning: "If it needs brighter trails, they have to be a lot brighter to reduce path loss to a level where signal becomes readable and there are a lot fewer of those available").

This is the point of a tilt in the path attenuation curve. This point is the value used for designing and optimising commercial meteor scatter links. Required particle size is about 0.4 mm of radius, mass 1 mg, equals to a visual magnitude of 5.0 on 144 MHz. On 50 MHz the particle has to be of 0.02 mm radius, 0.1 mg mass, and visual magnitude 7.5, too faint to see using eyes only.

Required electron density is calculated from:

q=fý/81

According to different sources, 30% to 56% of reflections are overdense on 50 MHz (depends on system sensitivity to detect faint meteors).

On shorter wavelengths, 1.6 m...0.5 m, or less, underdense trails do not have a steady state on forward scatter. Only the transient state exists. The reflection takes place only on small area at the meteor head. The path loss is worsened with the effect of wavelength raised to the power of 6, instead of compared to long wavelength equation, where the wavelength is raised only to the power of 2, or 3. This transitional wavelength can be anything between 10 cm to 100 m,

with extreme values of scattering parameters.
Using back scatter, the transitional wavelength is 2.9 m, so 144 MHz back scatter signals from underdense reflections are attenuated compared to forward scatter. The above is said to be valid also for overdense trails on shorter wavelengths using back scatter. I have not found any reference on forward scatter.

The difference of underdense and overdense trail is the mechanism that re-emits RF-energy is different. On underdense trails the RF-energy penetrates the trail and makes electrons oscillate and re-radiate energy, while on overdense trails, no penetration occurs and the trail is modelled, as a metallic cylinder reflecting the RF-energy.

The other difference is the change in the path attenuation vs. electron density graph, where the path attenuation is reduced less, when electron density increases, compared to underdense trail path loss.
In other words, increasing electron density from 10E+16 to 10E+17, causes less improvement on signal strength than the change from 10E+10 to 10E+11 electrons/meter.

There is one more difference with these trail types:

On underdense trails there is no polarisation change, or polarisation change caused QSB. Neither there is no diversity QSB.

On overdense trails there are both types of QSB at the later part of the reflection, when the trail dissipates and distorts. This causes the footprint of the reflection to be like a flag in the wind with the minimas and maximas moving fast on the footprint area causing QSB.

Geomagnetic storms (Aurora) has been observed to reduce radar observed meteor rates by 20-25%. Also geomagnetic disturbances reduces rates. Decrease in density gradient of the atmosphere at 100 km altitudes reduces peak meteor brightness and the peak trail electron density.

The 11 year variation of solar activity, has been shown to be one reason for long term variation of meteor showers. Showers are at their best, when solar activity is low.

Cooling of the upper atmosphere (ionosphere) by greenhouse gases have been assumed in some studies (E. Turunen & Ulich, 1997) to cause the F layer to descend significantly over the past few decades and this also caused the meteor layer to fall by 2 to 3 km and increase the pressure gradient, which has same the effect as low solar activity.

Mr. Jones has suggested the ozone as a destructive agent for meteor trails and this would cause some diurnal variation of the duration of overdense trails. Hence, it would make the diurnal variation ratio of visual vs. radio rates differ a little.

This of course raises the question, if the sunlit side of the atmosphere suffers minor reduction in density gradient and increase of ozone compared to dark side?
This would have a minor effect on enhancing communication at nigh time.

The transmission equation used for calculating path loss:

4 3
(1/16*pi)*(u0e/4m)ý*(W/R1*R2*(R1+R2))*((Gr*Gt*qý*sinýa)/(1-cosýb*sinýphi))

The polarisation effect in the equation gives the minimum reflected power. Up to 4 times more reflected power can be available from the possibility of electron resonance.
Electron density is replaced with a fixed value, as explained earlier.
All the other terms are constants, or geometry induced.

A general formula on duty cycle showing the effect of power increase is:

D = P^.6 for underdense trails and D = P^2 for overdense trails.

The equation indicates; an increase of +3 dB in transmit power, will increase the received echoes by 1.5 times:

P	reflections	
	U-dense	O-dense
using 100 W	10	10
using 200 W	15	40
using 400 W	23	160
using 800 W	35	640

The column to be used, depends on whether the link can use small meteors producing only underdense trails, or not.

Increasing antenna gain does not increase number of echoes, but enables more reflections from faint meteors to be observed (assuming uniform distribution of sporadic meteors). This is valid on short distance. With a shower and long distance things get a little bit more tricky.

The core of a meteor reflection, a "footprint" is like a boomerang, smoothing out to an oval and on the fringe areas almost to a circle. The size of this footprint is some 150 km by 50 km. There are some differences in the shapes and sizes of footprints from over- and underdense trails.

The basic equation for calculating T-wait:

T-wait= q/H*K exp(Tm/(wlý*cot(phi)ý/16*pi*D)) ln(1/1-P)

Power - T-wait relationship is:

T-wait = Tw0*(P/P0)^-0.6

CONCLUSION

Several important factors described in various scientific engineering, astronomical and astrophysical papers, are included in the Compact MS-Soft to provide information on the path and it's variations. This way you may avoid using non-optimal paths and save some time.

I do not claim the results accurate (for scientific analysis) for many reasons (even the professors say: "Let us presume the Earth is flat").

It would be an enormous task to prove how the results correlate with real world. In this sense, writing this software has been at the same time, both easy and difficult. The shortcuts are mainly in the trigonometry, but I believe they are mostly masked by uncertainties in basic meteor and meteor scatter parameters.

The shower data available in literature shows discrepancies and is additional source of errors, but it is a whole lot better than nothing!

6. WHAT COULD BE DONE TO GET MORE REFLECTIONS?

Easiest way is to have more output power, lower RX noise figure, improved receiver, optimise the time of the sked etc.
These are the things everyone knows about.
There has been less talk on the following subjects.

You could consider circular polarised antennas, or adjustable polarisation, as used on EME. On long distance contacts, this does not help much, because horizontal polarisation is close to ideal. On 50 MHz faraday rotation has some effect and it might be better to use CP.

There could be some advantage in SSB and slow CW work to have CP: In a long burst, the polarisation turns random after the first second (on 40 MHz) and with linearly polarised antenna this could cause QSB, while CP antenna would not suffer QSB for the this reason. (See Note 2.)

Diversity effect could be used. Unfortunately the antenna spacing required is beyond any reasonable distance for connecting the system with coax cables. Separation would have to be tens of kilometres.
Diversity QSB takes over once the trail starts to distort because of winds. Before diversity QSB starts, the proportions of signal strengths remain same on different receiving sites.

Alterable antenna radiation pattern and gain. This is also a difficult one to accomplish. Commercial links have used split beam produced by anti phasing horizontally stacked yagis, to enhance sporadic meteor performance. One could have two, or three different antennas with different gains to illuminate the reflection area in the sky. On less than 1000 km path, a short cross yagi should be used. On medium distances, two stacked yagis would be close to the optimum and for long distances, over 1800 km, four stacked yagis could be used. Horizontal stacking narrows the horizontal beam width and the whole scattering area might not be illuminated. Most of the above and more could be done with electronically steered arrays, but no such VHF antennas are used by amateur radio stations. The USN Rome Laboratories are doing some research on focusing a high gain antenna beam to a trail.

Throughput on CW could also be optimised:
I have derived from a digital MS link optimisation curve using maximum number of bits per transmission, the relative number of CW letters using under- and overdense reflections on 144 MHz for various distances.

Distance   Relative # of CW letters passed in:

km	single ping	single burst
1000	5	150
1500	2.5	75
2200	1	35

These numbers do not take in account link parameters and therefore can not be directly used for scaling proper CW speed.
By having adjustable RX bandwidth, knowing the ERP used and RX noise level, it could be possible to compute the optimum speed for CW.
I am afraid the equipment presently used for receiving high speed CW, can not fully handle the required speed range. This makes optimisation pointless.

You also should read R. A. Formato's (K1POO) article in Dubus 3/94.

Probably he has been trying the describe an antenna tested on some military link (See note 1). He knows it performs well in such use and knows what he is talking about.

What bugs me, is the antenna is vertically polarised, most ham antennas aren't. Crossed polarisation causes severe attenuation also on MS. The trail AZ orientation difference of 90 degrees for (nearly) horizontally oriented trails is said to be good on long distances. Vertical trails do not produce good reflection geometry over long distances. In fact they produce no usable geometry. SHAPE tests indicated 3.5 dB more signal on horizontal polarisation. (See note 2)

K1POO says a typical antenna is two by'ed vertical yagis. Where is this typical? Not in any MBC link study paper I have read and not in ham radio weak signal work (on 6m). Next he assumes the ground a flat, fully conductive plane, what it rarely is. Not flat, not conductive. Rarely producing the "ground tuck" he claims.

The losses referred as "substantial" on cables (on 50 MHz) are negligible. A power divider is essentially a low loss, air spaced coax cable and the connectors do not exhibit any more loss than equal length of coax, unless you use banana plugs or alligator clips.
Then K1POO proposes an 18 element monopole on the ground that requires 60 meters long conductive sheet for a ground plane. You can not rotate it. For ham use this approach is impractical. By stacking up large yagi array for 6m on a tower (with a small yagi for short distances), you are much better off, than with the monopole monster ruining the lawn.
If you wish to raise take off angle, use a relay to switch short coax delay line to the phasing cable of the upper yagi.

Theoretically he is correct, but he is a Ph.D. and I am not.....

<You got to be an engineer to cure a problem, but a wizard to find one!>

Note 1:

In NATO report SIII-4 in a study performed by US Navy, J.E Bickel of NOSC, US, explains the benefit found in the tests of using vertical polarisation in this shore to ship to buoy link, as a result of the low antenna height near the salt water. He presumes the advantage of vertical polarisation to be caused, by differences in the antenna radiation patterns produced, by the reflected signal from the sea surface.

Still, I ask: Is this kind of set-up typical in ham radio?

Note 2:

Mr. H. Nes explains the results of MS polarisation test done on 40 MHz on an 850 km link.

The set-up used crossed yagis at both ends fed either H, or V or CP. The receiving antennas were fed to two receivers and the IF output was monitored using an oscilloscope, by feeding the V RX IF to Y cannel and the H RX IF to X channel and observing the produced pattern. The results were; for the first second of the reflection the polarisation did not alter, but remained within +- 20 degrees.

After the first second the polarisation was random.

Using CP at both ends the pattern was an ellipse in favour of the H component by an average of 3.5 dB. The TX antennas were on a pole 40 m above the sea on a cliff. RX antennas were on 40 m towers on flat land.

This sounds more like the set-up we use and clearly, at least on this distance, shows the advantage of horizontal polarisation.

I interpret this: ALL underdense trails=pings, remain their polarisation! (Unless the wave has suffered from polarisation rotation common below 60 MHz).

I myself have the same conclusion from my tests on 88 MHz, where the same number of reflections was received using the "wrong" polarisation as what was the number of overdense trails received using correct polarisation. In other words, the wrong polarisation missed all the pings.

The 144 MHz CP-tests ran with OH2TI and DL6YHR in winter 1995 and 1996, also gave a hint to this same direction. This conclusion is based on low number of events on some cases, but in all cases horizontal polarisation gave better results, or at the least the score was even. Pings remained their polarisation, with bursts unpredictable variations occurred.

Note 3:
P. S. Cannon writes in RAE Tech. Rep. 85082: "....simple geometrical considerations show that delta h = 90 deg, however, delta v is not 90 deg. For propagation along the great circle path the horizontal component is, therefore, preferentially transmitted."

Another interesting aspect is the polarisation rotation that is worst at noon summer solstice and that should prefer the use of circular polarisation at least a the other end. On 50 MHz this effect is obvious.
