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What makes the Pings go Ping?

A Deeper Understanding of Meteor Scatter

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A Deeper Understanding of Meteor Scatter

- **A bit of History**
- **The principles behind meteor scatter**
  - Formation of meteor trails
  - Shower and random meteors
  - Types of meteor trail
  - Effect of operating frequency
  - Effect of path geometry
  - System throughput
    - burst duration, burst amplitude and burst frequency
- **Meteor Scatter system issues**
  - The antenna and its environment
  - Receiver performance

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A bit of history - Early work

1929 H Nagaoka - Proceedings of the Imperial Academy of Tokyo vol 5
"Possibility of radio transmissions being disturbed by meteoric showers"

1931 Greenleaf W Pickard – Proceedings of the IRE vol 19
"A note on the relation of meteor showers and radio reception"

1948 Lovell and Clegg - Proceedings of the Physics Society vol 60
"Characteristics of the radio echoes from meteor trails"

1954 Eshelman and Manning - Proceedings of the IRE vol 42
"Radio communication by scattering from meteoric ionisation"

1957 Forsyth and Vogan" - Proceedings of the IRE Vol 45
"The principles of JANET – a meteor burst communication system"

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The Formation of meteor trails

- Millions of particles or micrometeors are swept up daily by the Earth in its orbit round the sun.
- The majority burn up in the E region of the ionosphere without reaching the ground.
- The particles vary in mass from about 0.1 µg to 10kg
- Sizes from 200µm to 80mm in diameter.
- Masses distributed such that there is approximately the same total mass of each size of particle per day.
- Therefore there will be 10 times the number of particles of mass 0.1ug as there are of mass 1µg-etc.
- Their velocities on entry into the atmosphere vary from around 11 to 72km/sec

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Types of meteor

- Shower meteors
  - Remnants of comet tails going round the sun
  - Well known and predictable orbits which intersect with the earth's orbit at the same time each year.
  - Radiate from a fixed point in the sky and have names which relate to the constellation associated with that point.
    - e.g "Geminids" appear to radiate from the constellation of Gemini
  - Relatively infrequent appearance provide short term enhancements to a meteor burst path

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Types of meteor

- Random Meteors
  - Far more numerous and occur all the year round
  - Travel round the sun with no predictable orbit, and have no specific radiant point
  - Majority of useful sporadic meteors orbit the sun close to the plane of the ecliptic in the same direction as the earth
  - This gives rise to a diurnal variation in meteor activity giving a peak at around 0600 (local time at the path mid point) and a minimum at around 1800

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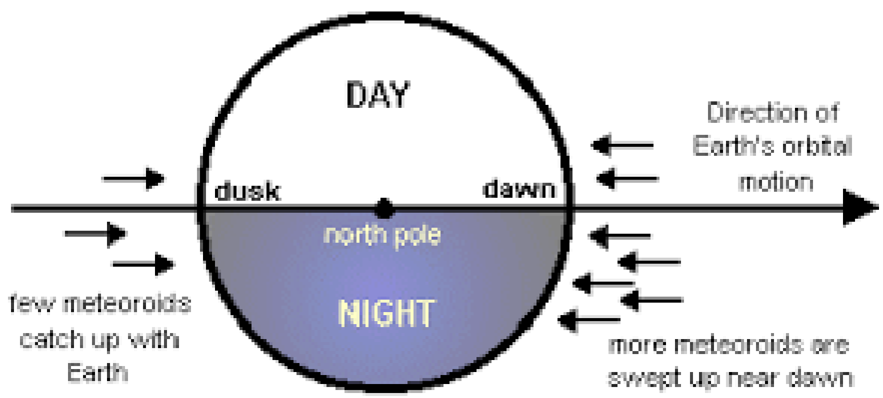
Types of meteor

- Random Meteors – Diurnal Variation
  - The morning side of the earth is travelling with the orbital velocity into the main flux of meteors.
    - Hence the relative velocities of earth and meteor are greater.
  - The evening side of the earth is rotating away from the meteor flux
    - only meteors with sufficient velocity are swept up by the earth's atmosphere



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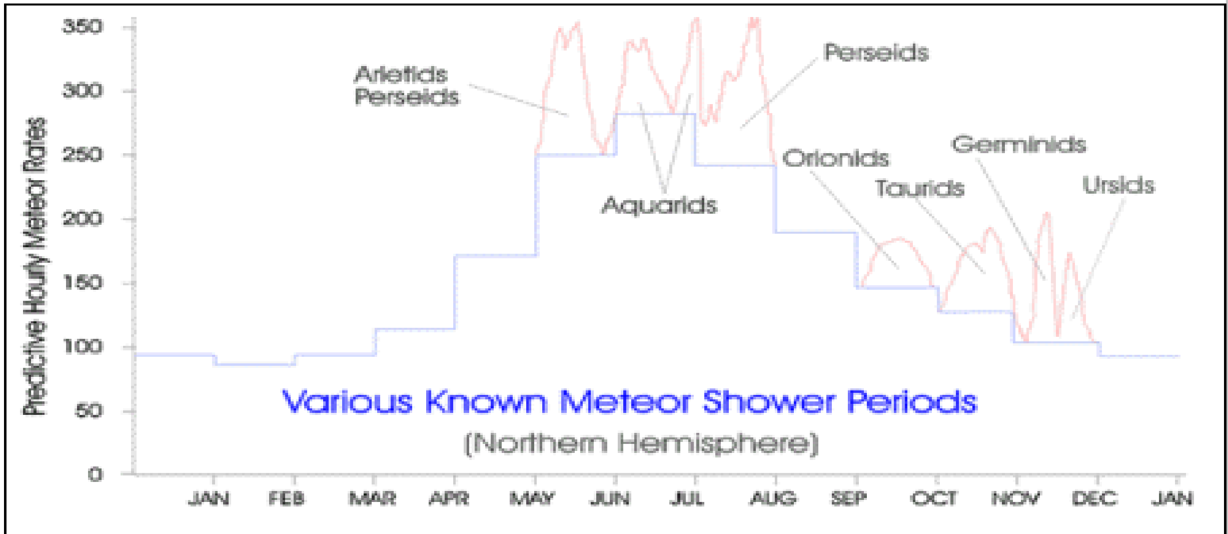
Types of meteor

- Random Meteors – Seasonal Variation
  - Sporadic meteor orbits are not uniformly distributed along the earth's orbit
    - Average meteor activity peaks around mid July and is at a minimum in February



Seasonal Variations of Meteor Rates

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The Formation of meteor trails

- As they collide with air molecules they leave behind a trail of ionised particles, mainly metal ions, and free electrons.
- Trail takes the form of a long thin paraboloid with the meteor at the head.
- The trail forms the short lived reflecting or scattering medium for HF and VHF signals.
- The electron line density D, a is measure of ionisation, depends on the mass of the meteor.

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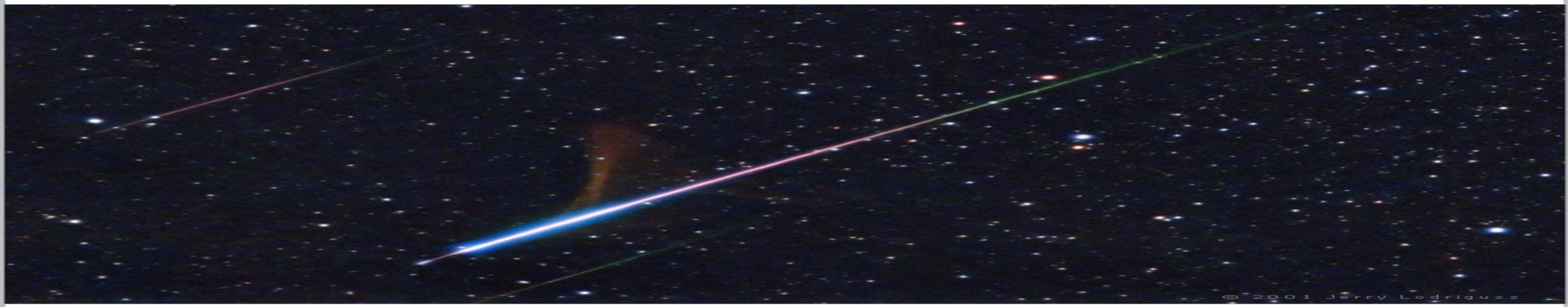
Types of meteor trail

- Underdense ("Pings")
  - Electron density is low enough to allow most of the incident energy to pass through it unaltered
  - Small amount energy is scattered in other directions



- Overdense ("Bursts")
  - Electron density is high enough for the trail to act as a highly reflecting surface

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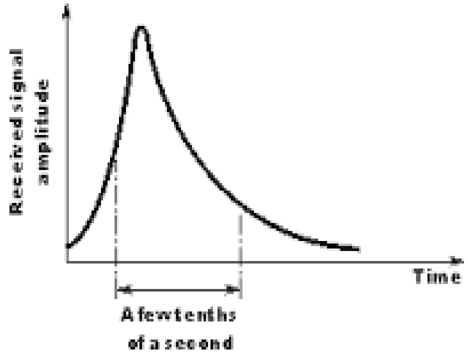
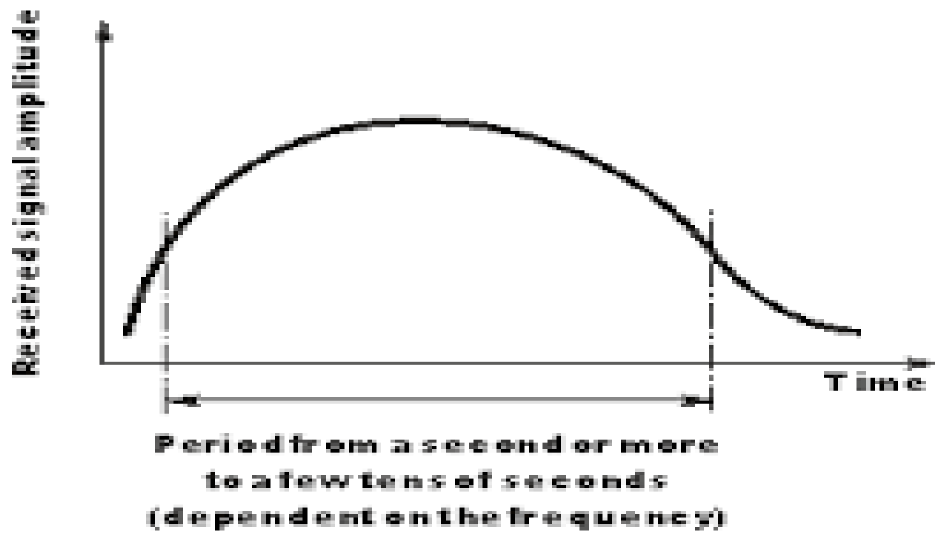
Characteristics of meteor echoes

- Underdense



- Overdense



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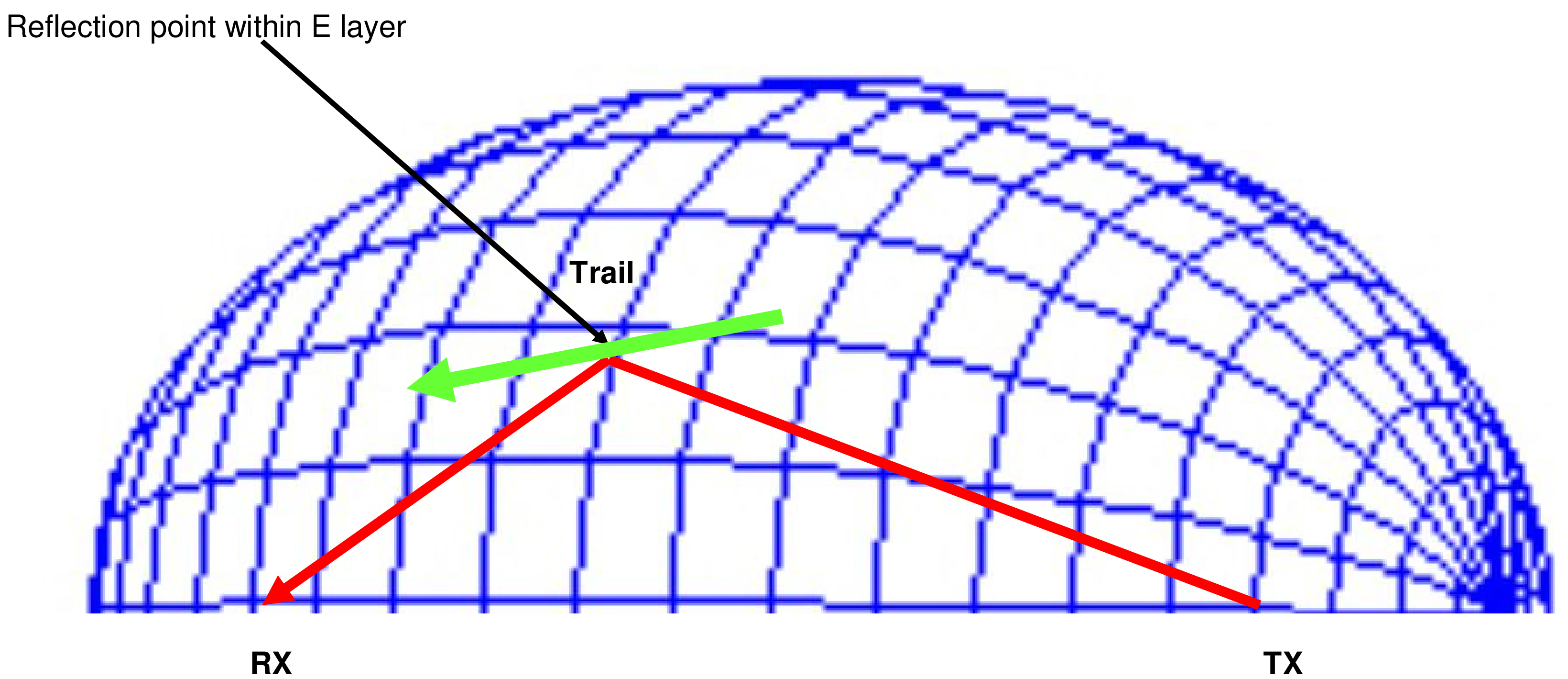
The principles behind meteor scatter

Path geometry – TX and RX must be at the focus of a “prolate spheroid”



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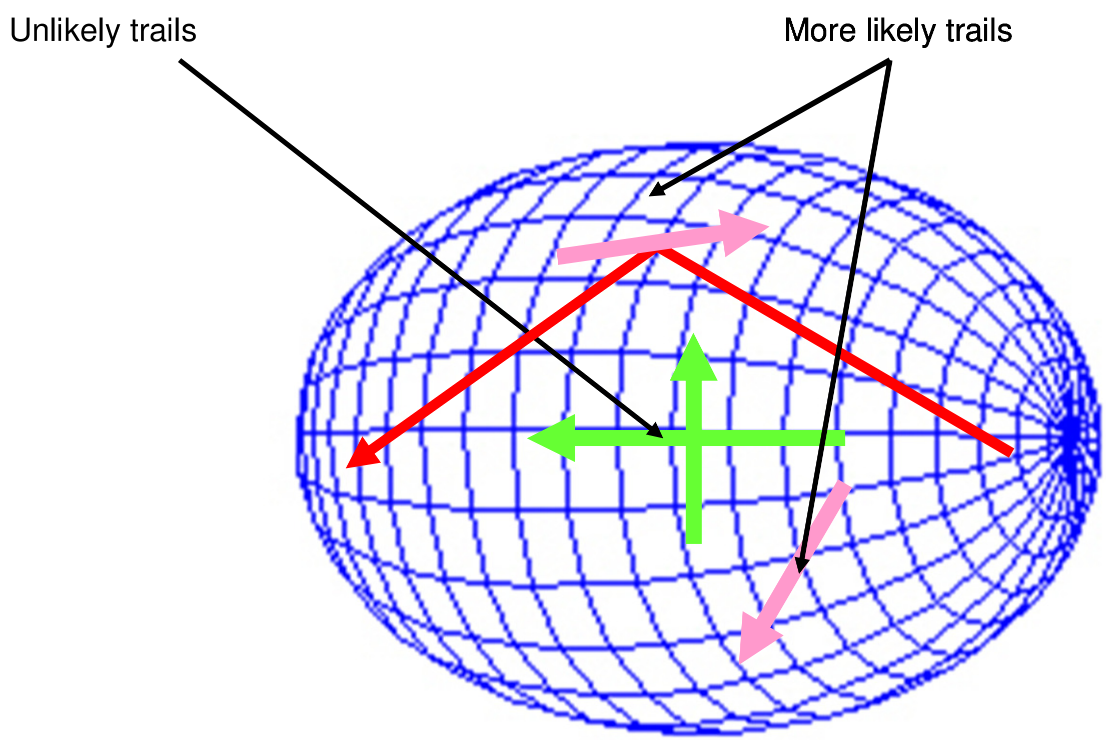
The principles behind meteor scatter

Path geometry – Plan view - The reason for offset “Hotspots”



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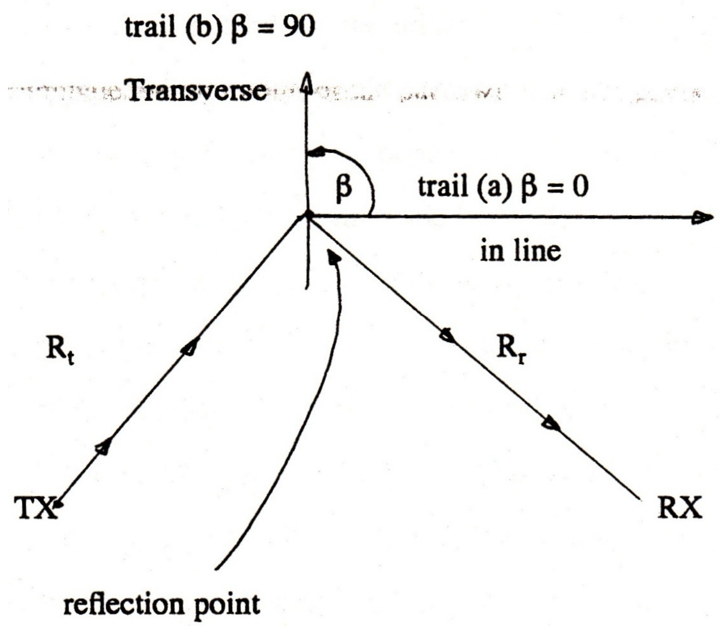
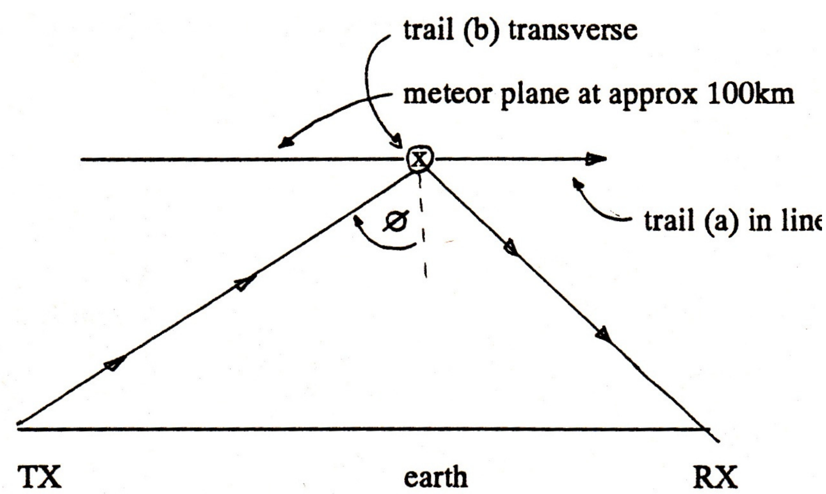
Path Geometry

It's all about the angles!



Path from above



Path from side

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Effect of Frequency

- ***Transition wavelength / frequency***
- Classic 1964 paper “Radio Propagation by Reflection from Meteor Trails” by George R. Sugar
  - “At long wavelengths the transient time of formation of a meteor trail is negligibly small compared to the total time that radio waves are scattered by the trail.
  - As the wavelength is decreased, the duration of this steady state decreases while the duration of the transient state tends to remain constant.
    For sufficiently short wavelengths only the transient state remains.”
  - Value is approximately 3.3 metres or 91MHz

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Simplified Path equations (skipping 3 pages of derivation :-)

Received power - Long wavelength, underdense trail

Exponential decay term (underdense shape)

$$P_r = K \exp(-8\pi^2 r_0^2 / \lambda^2 \sec^2\varnothing)\exp(-32\pi^2 Dt/\lambda^2 \sec^2\varnothing).$$

$$\text{Where } K = \frac{P_t G_t G_r \lambda^3 q^2 r_e^2 \sin^2\alpha}{16\pi^2 R_t R_r (R_t + R_r)(1-\cos^2\beta \sin^2\varnothing)}$$

Initial trail radius

Path loss proportional to cube of frequency

Polarisation term

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Simplified Path equations (skipping 3 pages of derivation :-)

Received power - short wavelength, underdense case

$$Pr = \frac{P_t G_t G_r \lambda^6 q^2 r_e^2 v^2 \sec^4\varnothing \sin^2\alpha}{4096\pi^6 R_t^2 R_r^2 D^2} \{\exp(-8\pi^2 r_0^2/\lambda^2 \sec^2\varnothing)\}$$

$$\left[1 + \left(\frac{v^2 \ \sec\varnothing(1-\cos^2\beta\sin^2\varnothing)}{8\pi D R_t R_r \cos\varnothing/(R_t+R_r)} \right)^2 t^2 \right]^{-1} \quad \ldots(x)$$

Long path = large phi = less loss
But see also R^2 terms

Polarisation term

Path loss proportional to ***6^th^ power*** of frequency

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Path equations (skipping 3 pages of derivation :-)

Trail duration = Time for signal to drop by 8.7dB

(to 1/e of it's initial amplitude)

Long Wavelength, underdense

$$\text{duration} = (\lambda^2 \sec^2 \varnothing)/(16\pi^2 D)$$

Long path = large phi = longer durations

Duration inversely proportional to square of frequency

Diffusion coefficient

Approx 0.63 of this value for short wavelength case

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The principles behind meteor scatter

- System throughput is a combination of:
  - burst duration
  - burst amplitude
  - burst rate

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Meteor scatter system issues

OK, so Life's too short for QRP!

BUT…..

Your antenna and it's environment are the key to success

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Meteor scatter system issues

The antenna and its environment

Elevation vs height

Noise levels

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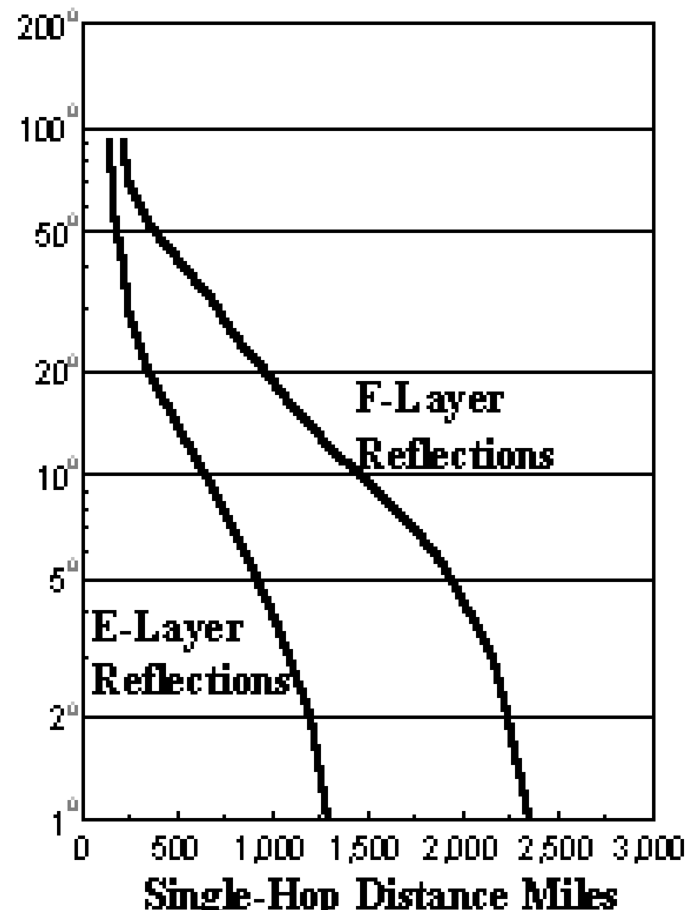
Meteor scatter system issues

- The antenna and its environment - Takeoff angle

This is a bad 50MHz DX antenna system

Angle of incidence of received signals (G3WOS “Zen and the art of stacking” 6 news)



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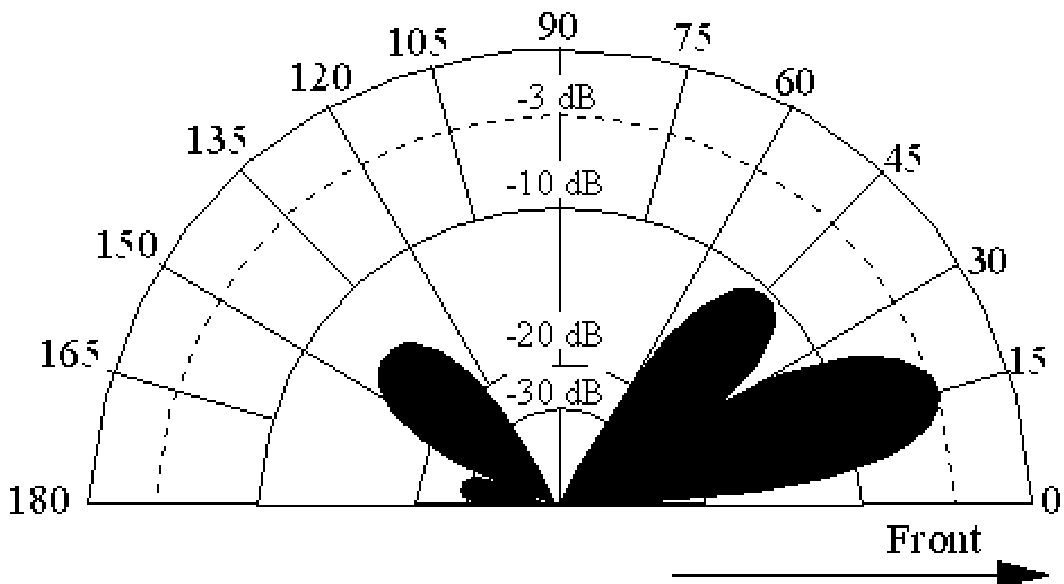
Meteor scatter system issues

The antenna and its environment - Takeoff angle vs height

H plane pattern of a typical 6 element Yagi at
1 wavelength above ground

(G3WOS “Zen and the art of stacking”)



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Meteor scatter system issues

- **The antenna and its environment**

- For 144MHz MS, Joe Taylor K1JT recommends –
  - "For out to 1600km an optimised 10-12ele Yagi is close to optimum
  - But a vertical stack of 2 would be better as it has a lower vertical beamwidth"

- But it needs to be high and "in the clear"

- For short paths something with a wider H- Plane beamwidth would be better.
- A horizontal dipole can be effective
- I've even used a zenith-pointing Yagi for very short paths on 50MHz!
- "End point reflection"

- Remember on 50MHz – generally your antenna will be "low" and have an elevated main lobe

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Meteor scatter system issues

- System Receive performance defined by signal to noise ratio.
- Signal power depends on the path loss
- Noise power is added noise from RX plus antenna Noise power kTB
  - i.e proportional to Temperature of what's in your antenna pattern
- Limited by our environment
- "Cold Sky" temperature (144MHz) is approx 350K
- Ground is around 290K

This is a bad 144MHz DX antenna system

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- Contributions to system Noise Temperature
  - FCC Bulletin no 70 July 1997
- All source temperatures add to overall system temperature

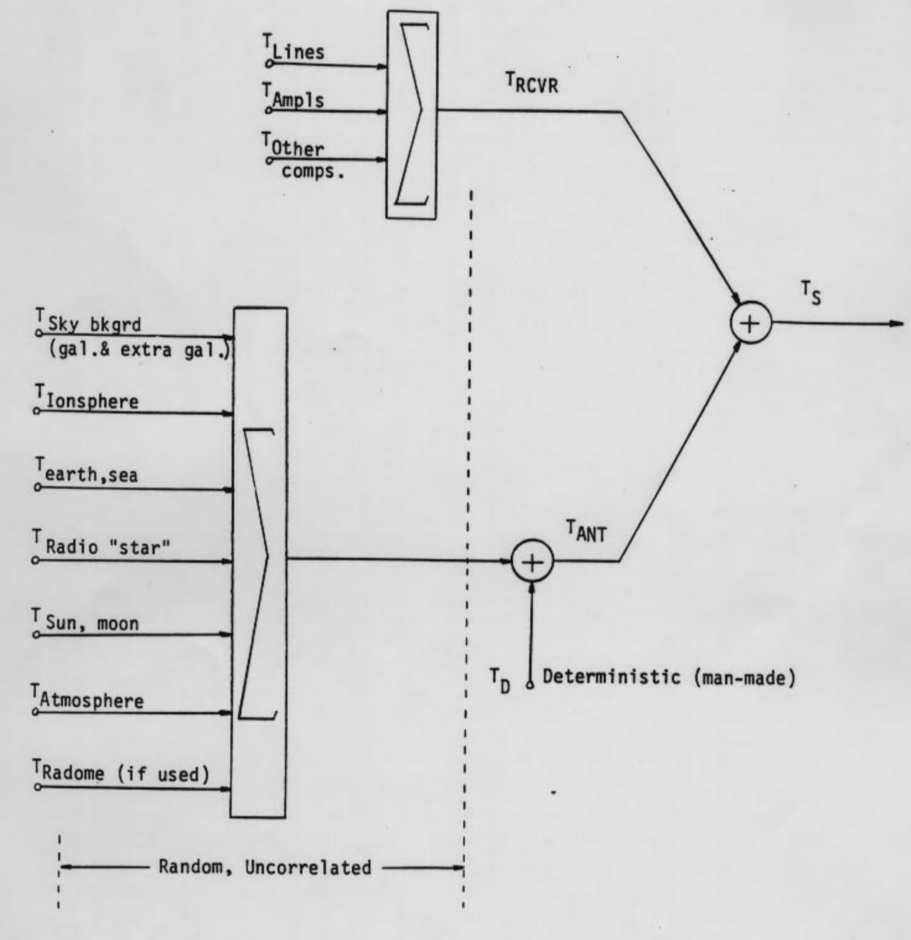

Figure 15 : Model Depicting Contributors to the System Noise Temperature

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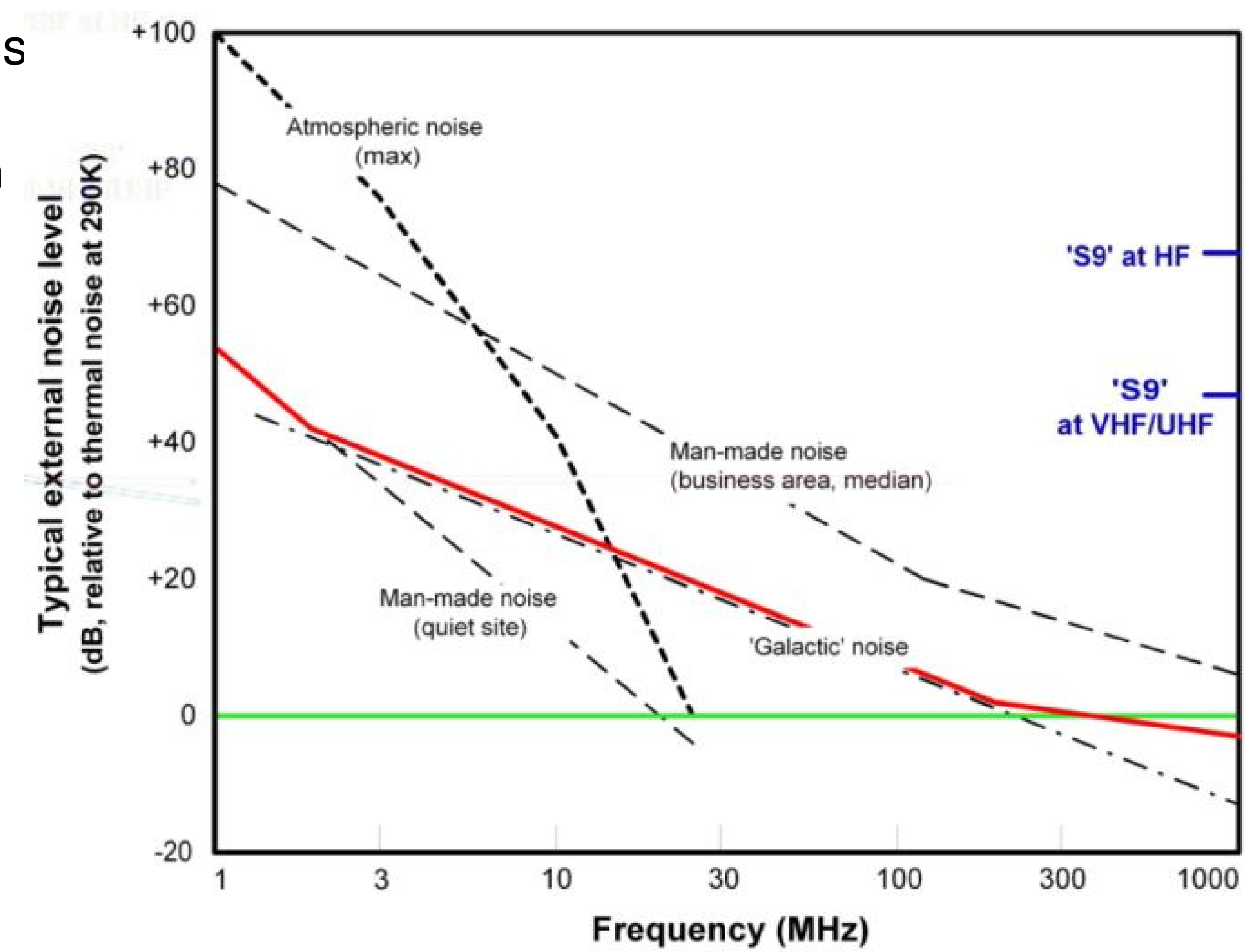
- Radio Noise levels 2008
  - G3SEK - IFWtech



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Meteor scatter system issues

- Main lobe “Looking” at the sky sees approx 300K at 144MHz
- For side and back lobes looking at ground add 60K+3K respectively = 363K (but could be looking at a man made noise source)
- If the antenna is pointed on the horizon, then at least half of the antenna pattern is illuminating ground
- Need to add half of horizon ground noise (290K) BUT
- With a +10dB excess man made noise you add half of 2900K!! Approx 1500K!!
- Plus around 30K for a preamp/losses giving 1893K

This is a bad 144MHz DX antenna system

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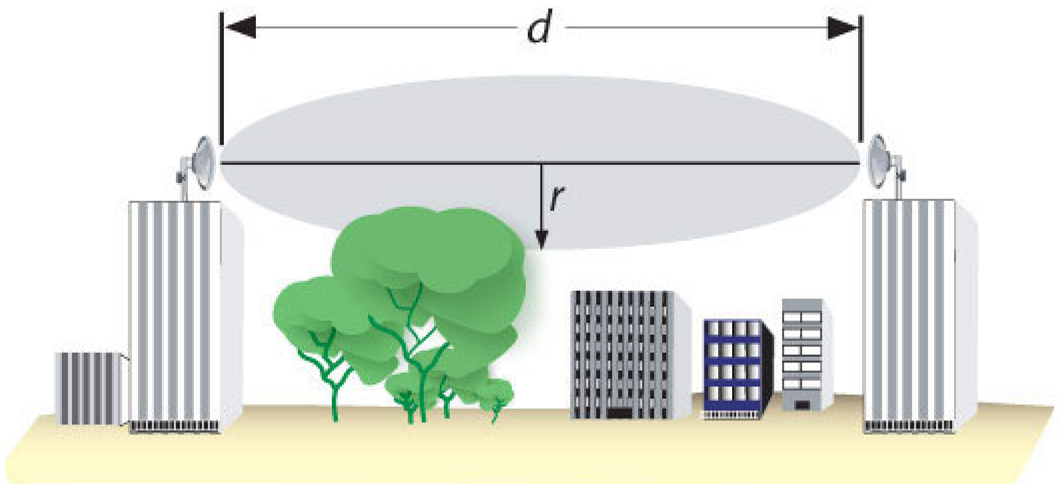
- Noise sources in First Fresnel Zone determine the main lobe



$$r_{(\text{in mts})} = 17.32 \times \sqrt{\frac{d_{(\text{in Km})}}{4f_{(\text{in GHz})}}} \qquad r_{(\text{in ft})} = 72.05 \times \sqrt{\frac{d_{(\text{in miles})}}{4f_{(\text{in GHz})}}}$$

Image

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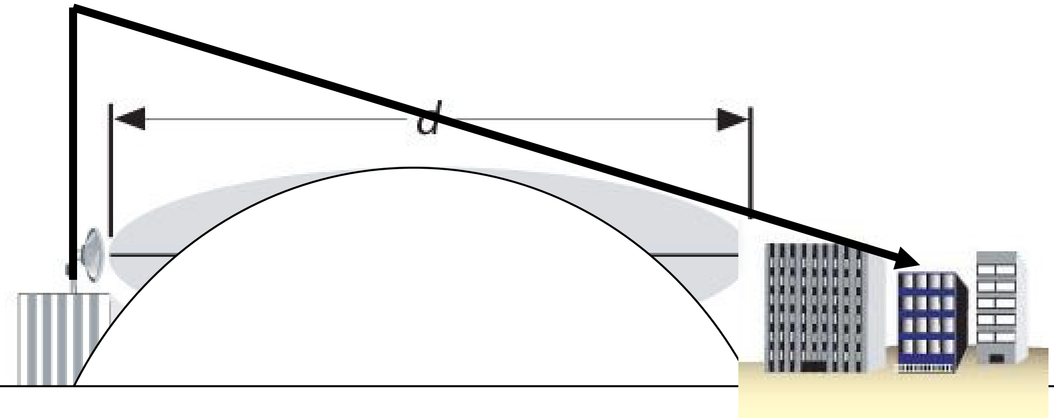
- Noise sources in First Fresnel Zone determine the main lobe
- So putting your antenna could make things worse if it can suddenly "see" a noise source on the horizon



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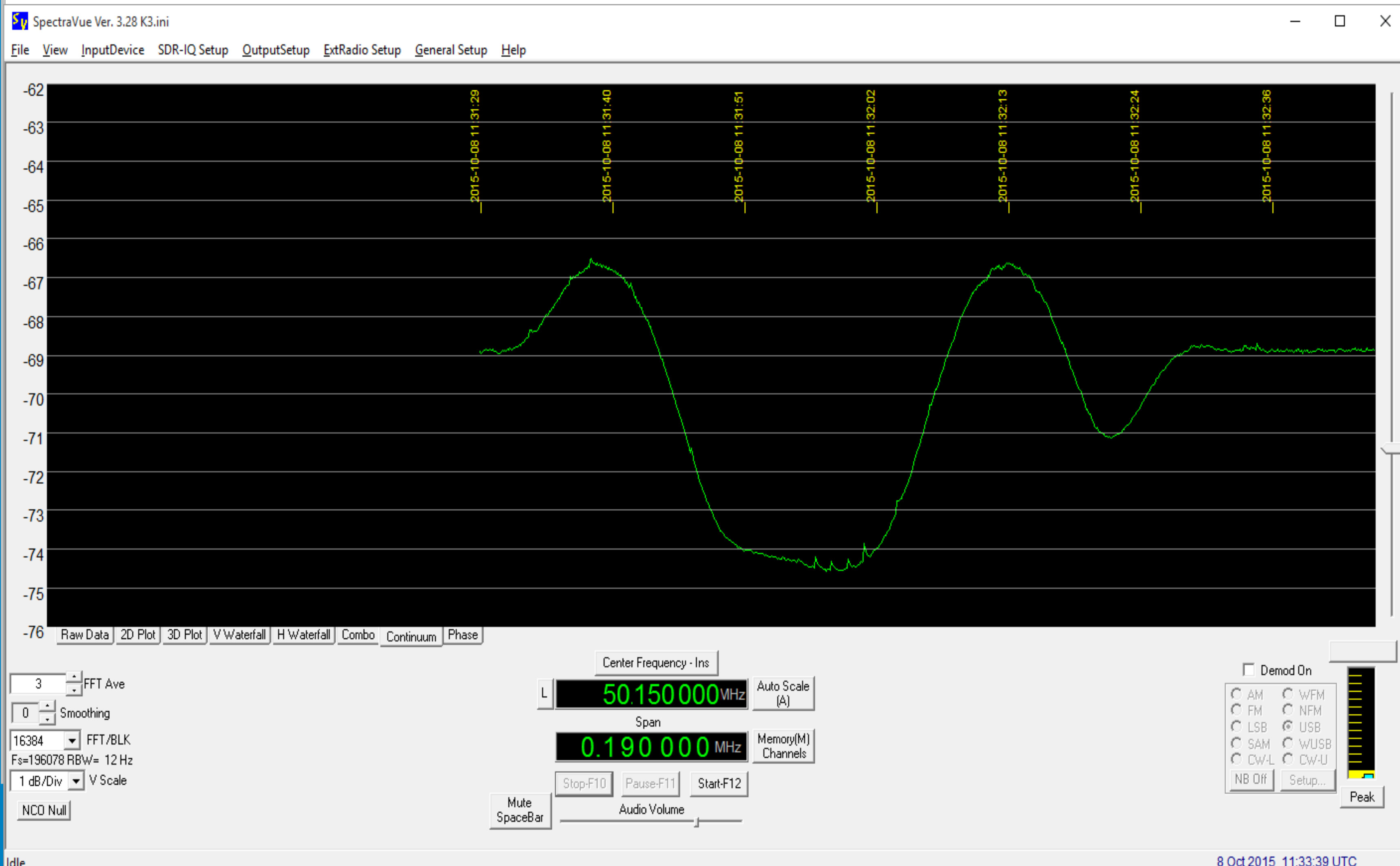
50MHz @ G4BAO with YU7EF Dual 5ele @8m



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Meteor scatter system issues

- Summary
  - Know your real antenna elevation angle
    - And use it to your advantage
  - Antenna gain is not everything
    - Lower gain wide H plane good for short paths
  - Measuring your site noise is easy
    - With AGC off compare RX noise power out with antenna to a 50 ohm load. (at antenna terminals

Acknowledgements and References

- Chris Rycroft (formerly G4FES)
  - who inspired me to find out more about MS - which ended up as a 6 year research project!
- Professor Paul Cannon OBE FREng.
  - Who encouraged me to do the research and did my viva voce in 1991
- Mullard radio astronomy observatory, Cambridge
  - Who let me play on their quiet site for four years
- Joe Taylor K1JT
  - Without who's work we'd still be using multispeed tape recorders and shouting "Roger Roger!!" a lot.
- Chris Gare, G3WOS and "Six news"
- G3SEK's IFWtech Website

This presentation will be available on www.g4bao.com in due course