Simulation and Comparison of Weak-Signal VHF Propagation

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PRESENTED AT:

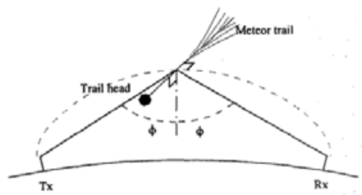
BACKGROUND

Space weather creates both adverse and beneficial propagation conditions for VHF communications. Analysis and simulations give a better understanding to these propagation effects.

Key parameters examined for study:

- Path Loss
- Propagation Distance
- Angle of Reflection
- Frequency Dependence

THEORY



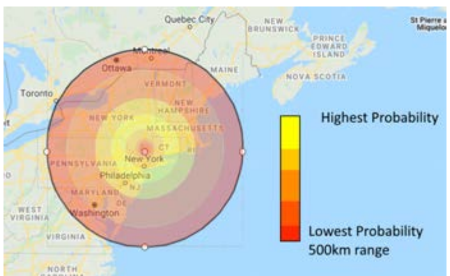
The 3 examined propagation modes transmit via reflection off of electrical surfaces as shown in the figure above.

METEOR BURST COMMUNICATION

The path loss for a radio wave propagated via MBC is modeled below. *G* is the respective antenna gain, *R 1* and *2* the distance to meteor from transmitter and receiver respectively, σ the echoing area of trail, and *a* as atmospheric loss factors dependent on height *h*.

$$\frac{P_r(t)}{P_t(t)} = \frac{G_t G_r \lambda^2 \sigma a_1(t) a_2(t_0) a_3}{64\pi^3 R_1^2 R_2^2}$$

This model was used to find the **optimal range for reflection meteors** above a central point. The model below shows the highest probability of propagation success around West Point, NY:



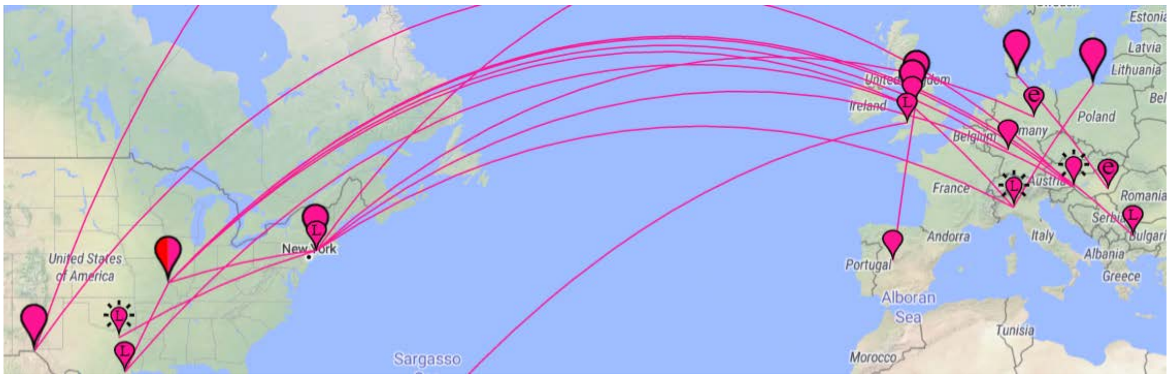
The figure shows a "bundt cake" model where meteors in the middle range have the most suitable propagation factors.

EARTH-MOON-EARTH

EME Contacts use the moon as a reflective surface with nearly 250 dB path loss and an 80,00 km round trip propagation distance. The below equation shows the path loss by an EME signal where η lunar reflection coefficient, r is the Moon's radius, and d is the transmission distance to the moon.

$$\frac{P_r(t)}{P_t(t)} = \frac{G_t G_r \eta r^2 \lambda^2}{64\pi^2 d^4}$$

Contacts were recorded during the ARRL EME Competition on 20 OCT 20 from *pskreporter.info* and analyzed for validation of the theoretical model.

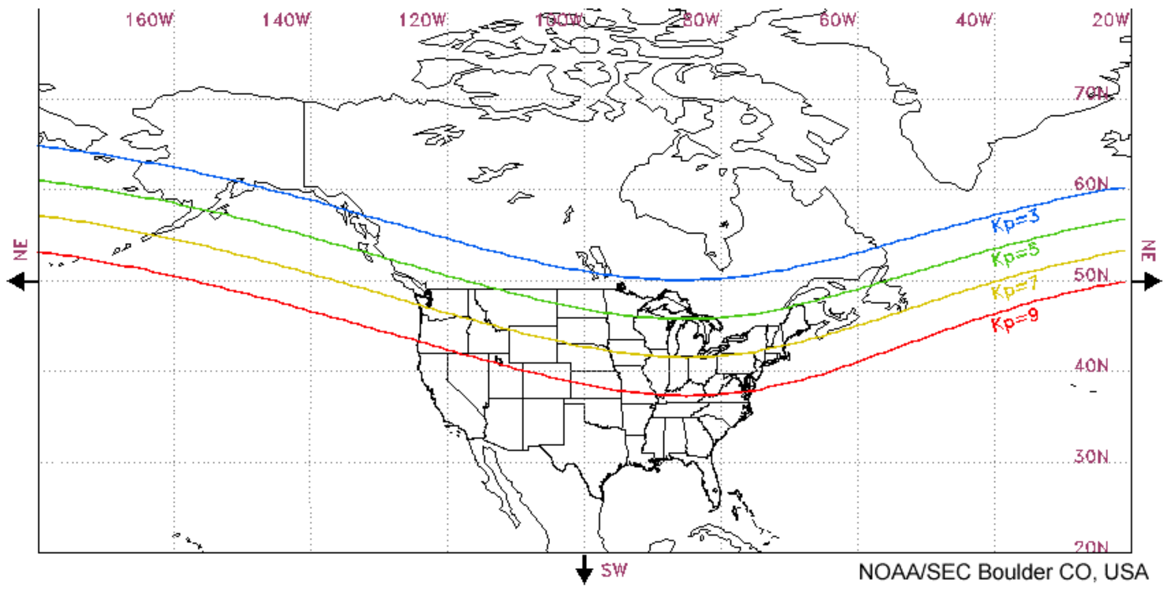


Stations HI8DL (**A** / Puerto Rico) and KU8Y (**B /** Michigan) had experimental values close to the generated model.

Parameter	A	B
Total Distance	76,3332 km	76,3334 km
Frequency	144.120.932 MHz	144.120.932 MHz
Antenna Gain	23.8 dB	28.84 dB
Power Output	1000 W	1200 W
Reception Strength	-23 dB	-17 dB

AURORAL PROPAGATION

Auroral Reflection occurs at high geomagnetic (K_P >4) indices.The following map illustrates possibilities of seeing the Aurora Borealis at increasing K_P levels with decreasing latitude.



CONCLUSIONS

The propagation modes are summarized in the table below:

Mode	Avg Path Distance	Loss for 2m	f dependency
Meteor Scatter	1,300 km	-200 dB	Inverse
EME	80,000 km	-252.1 dB	Linear
Aurora	2,100 km	-203.54 dB	Inverse

Propagation conditions change drastically when subject to space weather events. Analysis and characterization of these events allow for greater propagation forecasting and general understanding of space weather effects.

AUTHOR INFORMATION

CDT Nolan Pearce is a Junior at the United States Military Academy majoring in Electrical Engineering and minoring in Space Science. His research interests lie in digital communications and antenna theory to include atmosperic propagation. He is the president of the Cadet Amateur Radio Club (W2KGY) with the callsign KE8JCT.

Katherine J. Duncan specializes in the development of novel nanomaterials for next-generation communication systems. She received her masters of engineering in electrical engineering with an Optics Certificate (minor) from Stevens Institute of Technology and doctorate degree from New Jersey Institute of Technology. She is currently serving as a Visiting Research Fellow in the Department of Electrical Engineering and Computer Science at the U.S. Military Academy West Point. She is the current IEEE-USA 2021 President.

ABSTRACT

Space weather's intense variance has a seemingly random effect on radio wave propagation in the Very High Frequency (VHF) portion of the electromagnetic spectrum.

In this paper, key models are developed to analyze and estimate performance of wireless systems in weak-signal propagation mediums.

Chiefly, meteor burst communication, auroral propagation, and earth-moon-earth communication models are constructed and simulated with MATLAB.

The experimental results are confirmed through experimental testing and data comparison.

Overall, modeling of these space weather events is used in predicting the effectiveness of radio equipment through these weak-signal modes.

REFERENCES

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