PREDICTING IONOSPHERIC SCINTILLATION FOR SATELLITE COMMUNICATIONS

Capt Anne M. Hocutt (Air Force Reserve)

Avionics Laboratory
Wright-Patterson AFB OH 45433-6543

ABSTRACT

With the rapid increase in operational reliance on UHF satellite communications, the need for predicting communications outages has become apparent. One of the major causes of satellite communications outages is fading of the radio signal due to ionospheric scintillation. Operator-initiated techniques can be used to increase the probability of communicating through scintillation. Since they reduce message throughput in non-fading conditions, an operator should employ these techniques selectively. An ionospheric scintillation prediction model and display were developed for the Command Post Modem/Processor (CPM/P) for demonstration purposes. The CPM/P equations were then incorporated in a LOTUS 1-2-3 spreadsheet to allow predictions to be made using a desktop computer instead of the unique CPM/P equipment. Using this information, the operator can improve the message throughput of a UHF Satellite Communications system.

INTRODUCTION

With the rapid increase in operational reliance on UHF satellite communications, the need for predicting communications outages has become apparent. One of the major causes of satellite communications outages is fading of the radio signal due to ionospheric scintillation. Operator-initiated techniques can be used to increase the probability of communicating through scintillation. In addition, planners could take scintillation predictions into consideration when planning missions.

To demonstrate the usefulness of predicting which communication links have a high probability of fading, an ionospheric scintillation prediction model and display were developed for the Command Post Modem/Processor (CPM/P). To make the prediction technique more accessible and affordable, the equations from the CPM/P model were incorporated in a LOTUS 1-2-3 spreadsheet so the predictions could be made using a desktop computer instead of the unique CPM/P equipment.

CURRENT AFSATCOM USE

The UHF Air Force Satellite Communications (AFSATCOM) network is used extensively world-wide by the Air Force (Armstrong, 1978). The network includes satellites in geostationary equatorial orbit and in polar orbit. Strategic bombers and missile launch control centers communicate with air and ground Command Posts over these satellites. The new Milstar system also has a UHF component which will eventually replace the old strategic UHF networks (Schultz, 1983).

IONOSPHERIC SCINTILLATION

Ionospheric scintillation results when ion density irregularities in the ionosphere interfere with radio waves travelling through the ionosphere (Jursa, 1985). These signals are subject to variations in both amplitude and phase. The irregularities don't attenuate the signal but redistribute its energy. Figure 1 illustrates how these irregularities act as lenses, focussing the radio signal in one area and depleting it in another. Enhancements of 6 to 10 dB and fades of more than 20 to 30 dB in the UHF signal are possible during strong scintillation (Johnson, 1986). As these enhancements and depletions pass over a receiver or transmitter, the resulting radio signal may have fading from a few fades per minute to over 100 fades per minute, Figure 2.

Scintillation occurs in the auroral regions, the polar regions, and the equatorial region (Jursa, 1985), Figure 3. It does not occur continuously nor with the same intensity even in the same locations (Johnson, 1986). Scintillation is often characterized with two values: P, the probability of scintillation occurring, and S_4, the scintillation index, a measure of the strength of the fading should it occur (Jursa, 1985).

RADIO TECHNIQUES

There are two approaches to reducing radio message errors caused by ionospheric scintillation: hardware/software techniques and operator-generated procedures. Hardware and software techniques such as increased link margin, coding, and interleaving help reduce

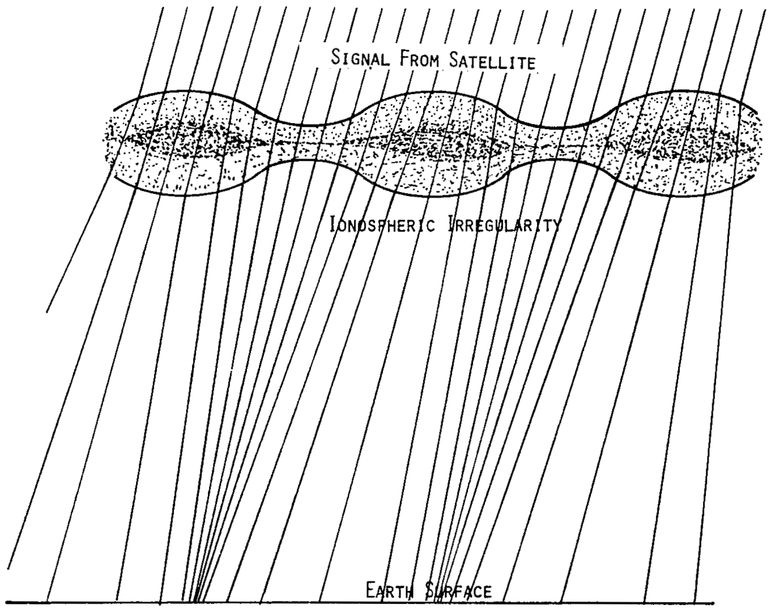

Figure 1. SIMPLIFIED REPRESENTATION OF IONOSPHERIC FOCUSING EFFECT

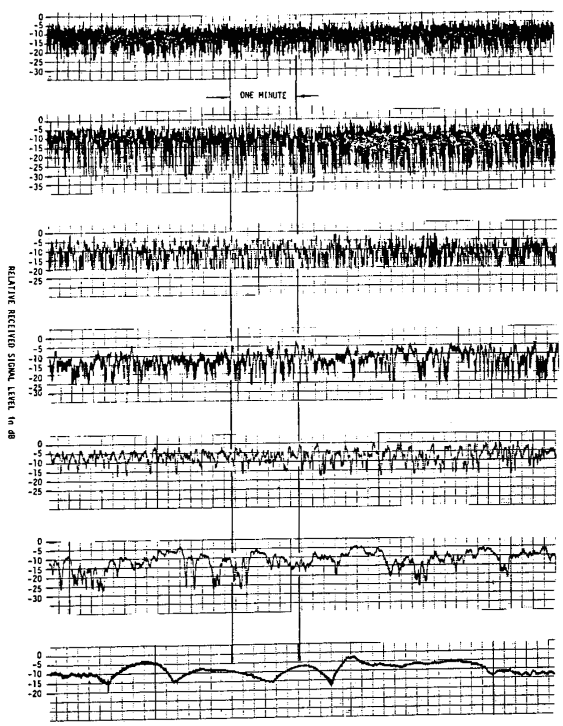

Figure 2. VARIATIONS IN HIGH-LATITUDE SCINTILLATION FADING RATE

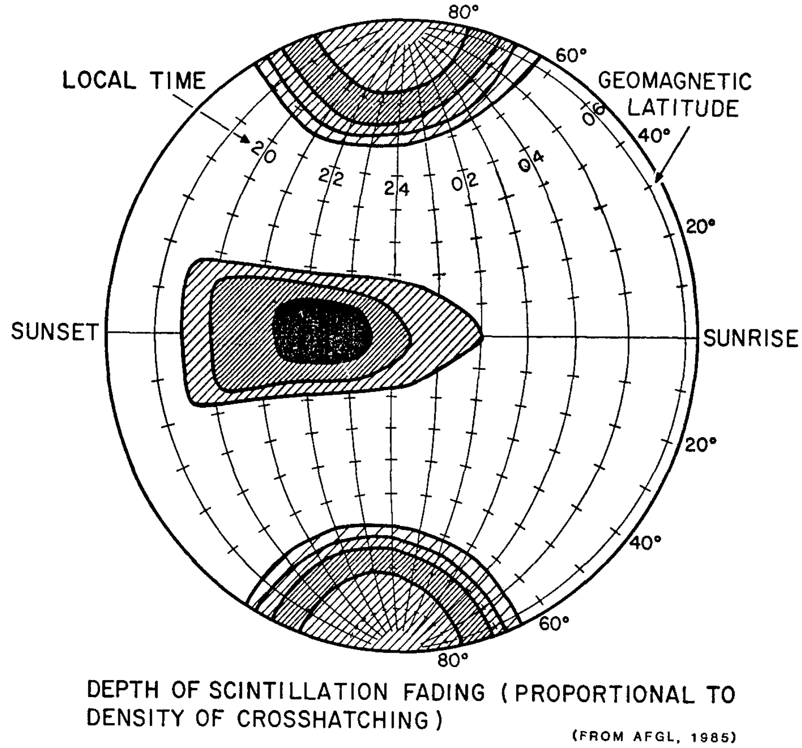

Figure 3. GEOGRAPHIC DISTRIBUTION OF IONOSPHERIC SCINTILLATION FADING

errors caused by scintillation fading. Current satellite communications equipment does not incorporate these to a sufficient degree to be relied upon solely. In addition, coding and interleaving have been shown not to be effective beyond a certain level of scintillation interference (Foshee, private communication). Until current satellite communications equipment can be upgraded, operator-generated procedures will form the bulk of the techniques used to increase message throughput probability during scintillation. These procedures include sending short messages and repeating messages. However, these redundancy techniques must be used selectively because they result in a lower message throughput rate during unfaded conditions.

SCINTILLATION PREDICTION

The problem of scintillation fading and what it does to communications has concerned scientists and engineers for several decades. Much data has been collected in an effort to provide a basis for a valid mathematical model. Over several years, a worldwide scintillation model named WBMOD has been developed under the sponsorship of the Defense Nuclear Agency (Jursa, 1985). The model includes terms to predict scintillation occurrence at all latitudes. Although this is the most complete model available to date, WBMOD has been calibrated quantitatively against limited worldwide data (Jursa, 1985; Fremouw, 1981). Physical Dynamics Incorporated continues to update the FORTRAN version of WBMOD they developed for the Defense Nuclear Agency. Their program currently runs on a VAX computer and provides scintillation values for one location at a time.

CPM/P SCINTILLATION MODEL

To demonstrate the usefulness of predicting which communications links have a high probability of fading, an ionospheric scintillation prediction model and display system were developed for the Air Force Wright Aeronautical Laboratories by Linkabit. This first embedding of a prediction model in an operational setting used equations which were approximations of the complicated scintillation process.

The actual mathematics were too complex to be exactly implemented in the time available. The programmers simplified and changed the mathematics since their task was to demonstrate what a display would look like, not to be precisely correct in their numbers. They changed the equations in the auroral region entirely and ignored the difference between geographic and geomagnetic latitude and longitude. The scintillation prediction is available to a user in the form of a world map display, Figure 4, and as numbers (S_4, P) describing scintillation conditions at a given location.

LOTUS 1-2-3 PROGRAM

The CPM/P is a unique and expensive piece of airborne hardware not available to the average communications operator or planner. In addition, its primary tasks are network control and communications, not scintillation prediction (Foshee, 1983). In order to predict scintillation indices without the unique CPM/P, the equations from its scintillation model were reformatted to a LOTUS 1-2-3 program. An operator can now predict scintillation conditions anywhere in the world from the CPM/P equations using a desktop computer. The operator calls up the program, enters the data, and prints out the results. Figure 5 shows a sample printout.

The LOTUS 1-2-3 program predicts scintillation indices that match the CPM/P results. While not exactly predicting real-world scintillation conditions, the LOTUS program will be useful for demonstrating the general concept of predicting scintillation conditions using a desktop computer. This concept could be very useful for operational work where knowledge of communication conditions is important.

CONCLUSIONS AND FURTHER WORK

Because ionospheric scintillation is a major disrupter of satellite communications in the polar, auroral, and equatorial regions, the ability to predict its probability of occurrence and strength would enhance a radio operator's effectiveness. The operator would be able to initiate message techniques, such as short messages and repetition, to increase message throughput probability. They would also be able to avoid message repetition in non-scintillated conditions because of its negative impact on message throughput when scintillation is not present.

The LOTUS 1-2-3 program implementing the CPM/P equations is the first step in predicting scintillation conditions on a desktop computer. It can be used to demonstrate the kind of capability which will be available to communications planners and operators of the future. The LOTUS program itself may not be useful operationally because the equations it implements do not exactly reflect the real world. Further work is needed to produce a program for the desktop computer which gives more accurate results.

REFERENCES

Armstrong, E.L., "AFSATCOM," Air Force Magazine, pp 80-85, July 1978.

Foshee, J. J., "Command Post Modem/Processor (CPM/P)," Proceedings of the 1983 Symposium on Military Space Communications and Operations, USAF Academy CO, August 1983.

Fremouw, E.J. and J.M. Lansinger, "Recent High Latitude Improvement in a Computer Based Scintillation Model," Proceedings of the Ionospheric Effects Symposium, Alexandria VA, April 1981.

Johnson, A. L., "UHF/SHF Satcom Propagation and System Design," from AGARD Report No. 744, "Special Course on Interaction of Propagation and Digital Transmission Techniques," October 1986.

Jursa, A.S. Editor, "Handbook of Geophysics and the Space Environment," Air Force Geophysics Laboratory (AFGL), Hanscom AFB MA, 1985.

Schultz, J.B., "Milstar To Close Dangerous C^3I Gap," Defense Electronics V. 15 No. 3, pp 46-59, March 1983.

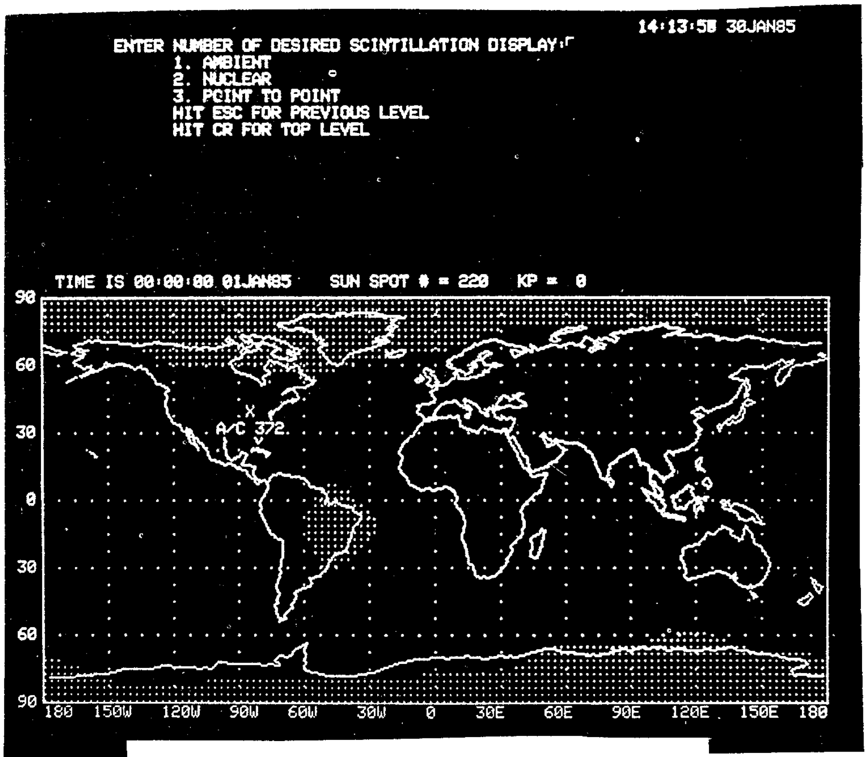

Figure 4. AMBIENT SCINTILLATION AREAS

SCINTILLATION CALCULATIONS USING CPM/P FORMULAS

LINE NO	LINE NO	HOUR (Z)	JUL DAY	S-F	K-P	LAT (N)	LONG (E)	S4 CPMP	P CPMP	S4 CALC	P CALC	VALID FLAG
2	2	2	18	90	0	65	0	30	27	31	28	1
8	8	0	15	90	0	65	0	27	25	28	25	1
20	20	2	15	160	0	65	0	69	62	69	62	1
34	34	22	177	160	3	65	0	75	68	76	68	1
154	154	0	180	170	2	0	0	100	30	100	29	1
186	186	6	185	150	3	0	90	7	1	0	0	0
189	189	22	248	100	0	0	0	100	35	100	35	1
197	197	2	340	150	4	0	-60	94	21	93	21	1
199	199	12	359	100	0	0	15	4	0	0	0	0
		21.67	15	220	2	0	5	64	0	63	1	1
		21.33	15	220	2	0	10	62	3	62	4	1
48	48	21	15	220	2	0	15	62	6	62	8	1
		20.67	15	220	2	0	20	66	12	66	13	1
1	1	10	4	220	4	-80	0	80	0	80	0	1
23	23	10	8	150	4	-80	0	49	9	49	9	1
35	35	10	3	175	2	-80	0	72	22	72	23	1
7	7	10	7	220	4	80	0	96	67	97	67	1
68	68	10	15	220	2	80	0	99	70	100	71	1

Figure 5. LOTUS 1-2-3 SAMPLE CALCULATION