Lucent Technologies, Bell Labs
Advance Technology Center of Excellence
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Lucent Technologies
Bell Labs Innovations

On Northpoint Field Trial in Washington DC
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Abstract:

Northpoint is proposing to provide terrestrial digital multichannel TV and wideband forward link Internet services using the 12.2-12.7 GHz spectrum that is currently used by Satellite Direct Broadcasting Services (DBS). Northpoint transmission is based on a patented approach similar to Space Division Multiplex (SDM) using directional antennas. There has been an interest on part of FCC as well as, DBS providers, Northpoint, and Lucent Technologies Bell Labs to get a precise understanding of the potential interference to DBS customers located at relatively close ranges to the Northpoint transmitter. During the months of August and September, Northpoint conducted a series of field tests in Washington DC area that provided useful data for this study. In this memorandum, we have provided some insight into the representative real world effects on the operation of the DBS customers at close ranges[1] including one at 0.17 Km from Northpoint transmitter. This analysis shows that for the site located at 0.17 Km from Northpoint Transmitter, measured degradation of received Eb/No for a DBS receiver is less than 0.23 dB with 95% confidence. Further, this reduction corresponds to a C/I of 24 dB under the test conditions. For general applicability, these figures can be scaled to other link conditions in conjunction with the DBS link budget and interpreted with respect to the link availability in terms of percentage of time and places. It is our opinion that for this level of interference the impact on the DBS services is negligible in all weather conditions.

[1] Due to the signal attenuation, the interference at locations beyond a few miles is not a concern.

Background:

To satisfy Federal Communications Commission s requirements. Northpoint services must coexist, on a non-interference basis, with the satellite direct broadcast services (DBS) that are licensed to operate in the same band as the primary users [1]. It is our understanding that Northpoint seeks to satisfy this requirement based on a patented approach using cell-based terrestrial transmitters with directional transmit antennas facing southward. With this arrangement. Northpoint wavefront nominally impinges on the rear of the DBS subscribers' antennas. Northpoint is currently seeking amendments to the pertinent parts of the current Code of Federal Regulations (CFR-47) which governs terrestrial use, through its affiliate Broadwave USA Inc.

During the last two years, Northpoint has sought and obtained three experimental licenses from the Commission to conduct limited field experiments and has filed supportive arguments and counter arguments for their patented approach. Before this experiment in Washington DC, Northpoint had completed two trials showing the fundamental viability of their approach in rural and urban environments in Texas. This experiment, which started in early August of 99, was conducted in Washington DC area. During this trial Northpoint conducted multicell transmission and demonstrated their service using Lucent Digital Video (LDV) equipment successfully. In addition, Northpoint gathered further evidence of non-interference to the DBS, here in the northeastern region of US where DBS elevation angles are more critical. Northpoint will separately publish a public progress report on this trial.

Bell Labs Specific Involvement:

Wireless and Multimedia System Development Group (WMSDG) in Arlington, VA is a group in Bell Labs Advanced Communications Technologies Center of Excellence centrally located in Holmdel, NJ. The group's collective background consists of complementary competencies in wireless communications system design, simulation, field optimization, and system implementation. Our parent center's charter is to help Lucent's BUs with development of new and advanced products of strategic importance to Lucent.

It is our understanding that there is mutual interest on part of Northpoint and Lucent Digital Video for partnering in bringing the terrestrial video service alternative to the consumers. LDV has therefore asked Bell Labs WMSDG to work with Northpoint during their field trial in Washington DC. WMSDG of Lucent

[1] There has been fixed microwave point-to-point services that used this band as well.

Technologies provided the following support and recommendation during the conduct of Washington DC filed trails by Northpoint technical personnel:

- Recommendation for experimental design of Northpoint field experiments with respect to transmission anomalies and interference measurements
- Recommendation for special measurement equipment and software for measured parameters
- Periodic observation of Northpoint field experiments and practices
- Recommendation for the analysis and reduction of the test data
- Technical opinion with respect to the experimental results

This technical memorandum provides an interim observation and evaluation of some test results collected by Northpoint in Washington area during the months of August and September.

Objective and Extent of the Tests:

Northpoint trial objective in Washington DC experimental transmission were as follows:

a) Further evaluation of interference effects on DBS transmission in single cell and multicell scenarios
b) Demonstration of their multichannel digital transmission service using Lucent Technologies multiplexer.

The test in category (a) examined coexistence of Northpoint Technology with Direct Broadcast Satellite (DBS) systems. Where applicable, special effort was made to locate the test sites to include transmission anomalies such as multipath signals due to reflections from buildings or bodies of water. Northpoint also conducted tests with multiple repeater/transmitters (multicell scenario) to examine the effect of overlap areas.

Category (b) test was a limited service demonstration to investigate the ability of the Northpoint Technology to provide a quality multichannel video service using Lucent's multiplexer. Northpoint successfully demonstrated this to various interested parties.

Test Metric:

The metrics used for category (a) tests were both quantitative as well as qualitative and included the following:

- Change of signal strength pointer[2] (SSP)
- Indication of increased noise in the DBS system using spectrum analyzer
- Presence of a good DBS picture using multiple DBS consumer receivers
- And link quality measure of bit error rate (BER)[3]

The last metric was of particular interest to Bell Lab. Elaborate work has been done by Northpoint to model the exact C/I due to the Northpoint transmission at various distances and its effect on performance of DBS consumer receivers. It is however generally impossible to realistically model signal environments with possible multipath and diffused reflections. Field measurements with realistic scenarios provide the opportunity to include such anomalies with relative ease. We paid special attention to the effect of Northpoint transmission in real world scenarios on the bit error rate of the DBS system. This report concentrates on the result of this particular test and summarizes our observation of the outcome.

Design of Experiments:

Eb/No is a generally accepted metric for assessing the quality of a digital communication link. This parameter is uniquely related to the transmission quality metric (bit error rate), and the link margin and availability. Our objective was to devise an efficient experiment to observe any changes in the mean Eb/(No+Io)[4] of the DBS received signal in presence of Northpoint transmission.

Theoretical analysis and previous Northpoint tests indicates that such a change is in general small if any and certainly not directly measurable using spectral power measurement. This is especially true for most practical field scenarios (i.e. C/I~ 20 dB). Therefore deterministic judgment as to the validity of the changes in the measured data is hardly possible for most practical field scenarios. Our approach for a meaningful test was to perform paired statistical sampling of the effects on the DBS Eb/(No+Io) with Northpoint transmitter ON and OFF. We took six sites, mostly located within less than a mile from Northpoint transmitter. Tests at these sites were conducted over several days at various times of the day using the same process each time. At each site, Eb /(No+Io) was automatically measured, using a laboratory grade DVB demodulator-decoder[5]. Data was recorded for consecutive periods of time when Northpoint transmitter was ON or

[2] The Signal Strength Pointer (SSP) is an indication of DBS signal strength, it is a feature of the consumer DBS set top and is intended to aid the consumer in properly pointing their antenna.
[3] Indirectly assessed by monitoring received Eb/(No+Io).
[4] Eb/(No+Io) is uniquely related to the BER using modulator-decoder performance curves.
[5] Variable rate demodulator model NTC /2063 manufactured by NewtecCy N. V. of Belgium, compliant with DVB standards (EN 300421).

OFF. The order was either OFF/ON or ON/OFF or OFF/ON/OFF with roughly equal test time. Total test time for each site was nominally 45 minutes, with samples taken approximately every 10 seconds. The intent was to form samples for further analysis off line.

Test Setup:

Transmitter:

The tests were performed around the Northpoint experimental transmitter[6] site on the USA Today building at 1000 Wilson Boulevard in Rosslyn, Virginia.

Transmitter apparatus consisted of a custom horn antenna[7] fed with a QPSK modulated carrier from a transmitter[8] with Digital Video Broadcast Format representative of potential Northpoint transmission. Transmitter equipment was set up on the rooftop and connected to the horn antenna, which was hanging over the parapet 5' below the roof line. The connecting transmission line was a 14' EW127 waveguide[9]. Transmit power was monitored, through a coupler using a HP power meter, both by an operator and automatically using VEE software. Automatic recording of power level was made every 3 seconds. Northpoint transmitter spectrum was overlapping the tested DBS transponder spectrum. Following table provides further details of Northpoint transmitter.

Table 1. Northpoint Experimental Transmitter Parameters

Parameter	Nominal Value	Unit
Transmit power	12.5	dBm
Carrier Frequency	12.47	GHz (DBS transpndr 18)
Polarization		Horizontal
Transmit Ant. Beamwidth	110	horizontal
	17	vertical
Tilt		None
Boresight Azimuth	113	degree
Modulation		QPSK
Symbol Rate	20000050	Symb/s

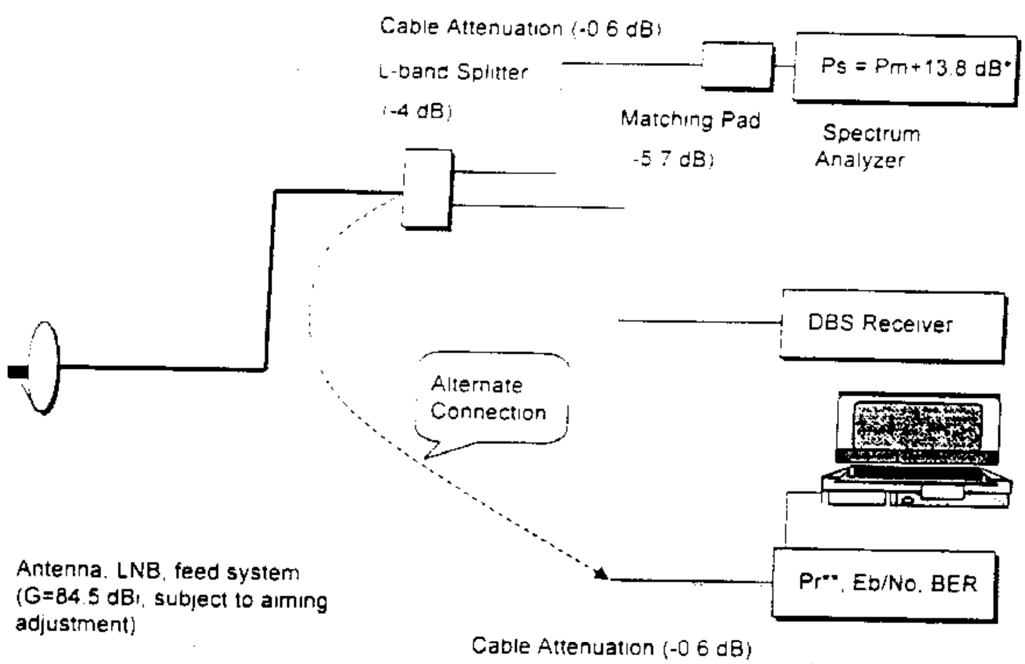
[6] (WA2XMY)
[7] Seavy Engineering Model
[8] LNR Communications Model
[9] Andrew Corporation

Receiver:

Receiver equipment was in a mobile test van. which was equipped with a towed boom lift supporting several DBS receiving antennas and an AC power generator. Receive antennas were commercial DBS offset feed parabolic 18" dishes with integrated LNB and L-band downconverter. The van had sufficient equipment for receiving and monitoring Direct TV and Echostar transponders as well as Northpoint transmitter. all displayed at the same time. Besides the DBS equipment and special receiver-decoders, the van included a spectrum analyzer, calibration signal generator, and necessary cables and connections for monitoring the desired signal line.

Monitoring and processing of the signals were performed on the block down converted L-band signal from the corresponding antenna LNB. All antennas were mechanically adjusted for best boresight view of the corresponding transmitter/transponder. Northpoint field personnel using in-line signal meter as well as the DBS on screen SSP made antenna adjustments.

Following figure illustrates the typical receiver setup and calibration of received power.



* Pm is measured spectral density im 1 MHz. 13 8 = 10*log (24 MHz. transponder flat bandwidth approx.)

** Pr = Ps+4+5 7 = Pm + 23.5 dBm

Figure 1. Typical receiving configuration and setup calibration

Newtec Integrated Receiver Decoder (IRD) was the test instrument used for BER tests analyzed in this report. This unit is a DVB compliant receiver-decoder equipped with a serial port where all receiver parameters such as internal temperature, received signal level, carrier and clock frequency offset, output BER, Eb/(No+Io), available link margin[10], alarm and sync indication at all levels, are available for monitor and download to a PC using a software package provided by the manufacturer.

Receiver Site Characteristics:

Northpoint previous tests as well as comments by DirecTV indicated that Northpoint interference level at distances beyond a few miles from the transmitter is indeed not an issue. Therefore the sites for BER test were selected to be mostly within a mile of the Northpoint transmitter. Furthermore, the sites provided a mix of azimuth relation between Northpoint transmitter antenna and DBS look angle. The criterion was to select sites that are a representative sample of the practical scenarios with potential Northpoint interference to DBS receivers. These test sites were a subset of all the sites that were tested by Northpoint. Following table lists some important attributes of the sites where BER test was performed.

Table 2: Specific Attributes of the BER Test Sites

Receive Site Name (Transmit site USA Today)	Site No	Ground Elev. AMSL (ft)	Distance From NP Tx (mi)	Relative direction to Tx brs (deg)	Measured NP spectr density (dBmi/MHz)	Relative azimuth DBS to NP (deg) **
Arlington Cemetary	7	36	0.86	47.5	-107	295.5
River Place Apts.*	1	65	0.11	76.6	-108	324.6
Roosevelt Island	1A	40	0.18	-87.0	-108	161.0
Federal Construction Site	10A	30	0.26	34.2	-108	282.2
Kennedy Center	3	20	0.71	-28.6	-108	219.4
Anacostia	19	15	4.20	1.4	-123	249.4

* Northpoint signal strength at this site is considerably above the calculated LOS which suggests other propagation phenomenon, ** Echostar transponder at 119 W

[10] Difference between measured Eb/No and required for the device.

Referring to Table 2. we believe these sites represent a good mixture of real world scenarios because:

1. Five of the six sites (7. 1. 1A. 10A. and 3) are within 1 mile of the Northpoint transmitter. Three are within quarter of a mile (1 1A, 10A)
2. Five of the six sites (1, 1A, 10A, 3, and 7) are among all the sites tested and exhibited highest signal strength from Northpoint transmitter.
3. Two of the sites (1 and 1A) are among the sites that exhibited substantially larger received power as measured compared to the calculated LOS power -- suggesting presence of additional propagation phenomena.
4. Four out of six sites (7, 10A, 3, and 19) are within the 3-dB beamwidth of the Northpoint transmitting antenna beam pattern.
5. Two of the six sites (3 and 19) are located such that Northpoint transmitter relative azimuth is close to the highest side lobe gain of the DBS antenna [11]. Relative azimuth of 180-degree occurs when DBS antenna is pointing away from the Northpoint transmitter.

Data Analysis Algorithm:

Our first objective is to see if the gathered data presents sufficient evidence to indicate that the DBS mean Eb/(No+Io) is less with the Northpoint transmitter turned ON. Secondly, we want to quantify this difference, if any, so that we can generalize the outcome to assess its impact on DBS performance and make comments concerning other untested scenarios.

To accomplish these two objectives we resort to the following statistical analysis procedure:

1. We examine the distribution of gathered data for each site and each event, Tx OFF and Tx ON. Approximately normal distribution shape is expected for an experiment of this nature.
2. We take two equal size array of data form each site and measured event, Tx OFF and Tx ON:

$$Y_1 = [\ y_{11} \ldots y_{1n}]$$
$$Y_2 = [\ y_{21} \ldots y_{2n}]$$

Where n>100.

[11] Reference DirecTV presentation of 2 March 99 filing to the FCC in the NPRM, page 10.

3. We form an array containing the difference of each paired sample sets[12]

$$D = [\, d_1 \ldots d_n]$$

4. We calculate the mean d_{mean} and variance s_d^2 for the elements of this array.

$$d_{mean} = (\Sigma\, d_i\,)/n$$
$$s_d^2 = (\Sigma\, (d_i - d_{mean})^2)/(n-1)$$

5. We then test the hypothesis for the expected difference being zero. Specifically, we are concerned with detecting whether the ON period Eb/(No+Io) is less than the OFF period Eb/(No+Io). At first glance it would seem that there is a difference between the population means, we would like to check this conjecture with a statistical test outlined below. The proper analysis of the paired data would utilize the difference array to test the hypothesis that the average difference is equal to zero, a statement which is equivalent to:

$$H_o : \mu_d = 0$$

6. We will use a paired-set statistical test and the rejection region for the test will be located in the upper tail of the t-distribution.
7. Referring to standard tables[13] for t-distribution, we find the critical value of t. We use alpha=.025[14] for given data set degree of freedom, df. Note that for our large data sets the degree of freedom is approximately equal to the

[12] A t-test for two sets with unequal variance also yielded approximately the same results. However, it is not peculiar for the two-set unequal variance test to fail if a binomial paired test is the only appropriate test.
[13] Table of Percentage Points of the t-Distribution, Computed by Maxine Merington, Biometrika, Vol. 32, p300.
[14]For a two-tailed t statistic this means that 99.5% of the time we will make the right decision about the outcome.

aggregate number of data samples. Since this is larger than 100 [15] for each of the six sites, we can use $t_{0.025} = 1.960$ as the critical value for t from the table.

8. We calculate the value of test statistics t, for each site:

$$t = d_{mean} / (\sqrt{s_d^2/n})$$

9. And compare calculated t with the critical value obtained above. If it does fall in the rejection region, i. e. greater than the critical value, we will conclude, with a 0.05 level of significance, that there is a reduction of mean of Eb/(No+Io). Otherwise we conclude the opposite if the calculated t is below the critical value.

10. If the above hypothesis is rejected, then we calculate the estimate of difference and the 95% confidence margin.

$$E(y1i-y2i) = d_{mean} +/- 1.96\sqrt{(s_d^2/n)}$$

Before proceeding with the analysis of the data, it is necessary to qualify some assumptions inherent with this algorithm -- "Moderate" departure from normal distribution for the test sample populations do not seriously affect the distribution of the test statistics and the confidence coefficient for the corresponding interval. However, it is essential to maintain a minimum variance in the measurements of the quality characteristics of a process. Measuring instruments must provide unbiased readings with relatively small error of measurement. Although bias can be corrected[16], the precision of the instrument is usually a function of instrument design, and can therefore not be corrected. Variance is fundamental to procedures for making inferences about population means. As will be discussed later, we take special precautions in our interpretation of the results so as to prevent any error due to a suspiciously large variance.

Data Analysis Results:

Figure 2 shows distribution of data for all six sites. We observe that the distribution for site #19 is excessively broad (Tx ON condition). We believe this

[15] A degree of freedom greater than 30 is considered reasonably large for statistical accuracy of this test.

[16] We randomized the order in which we took the measurements (ON/OFF, OFF/ON, OFF/ON/OFF as well as time of the measurement) for this purpose.

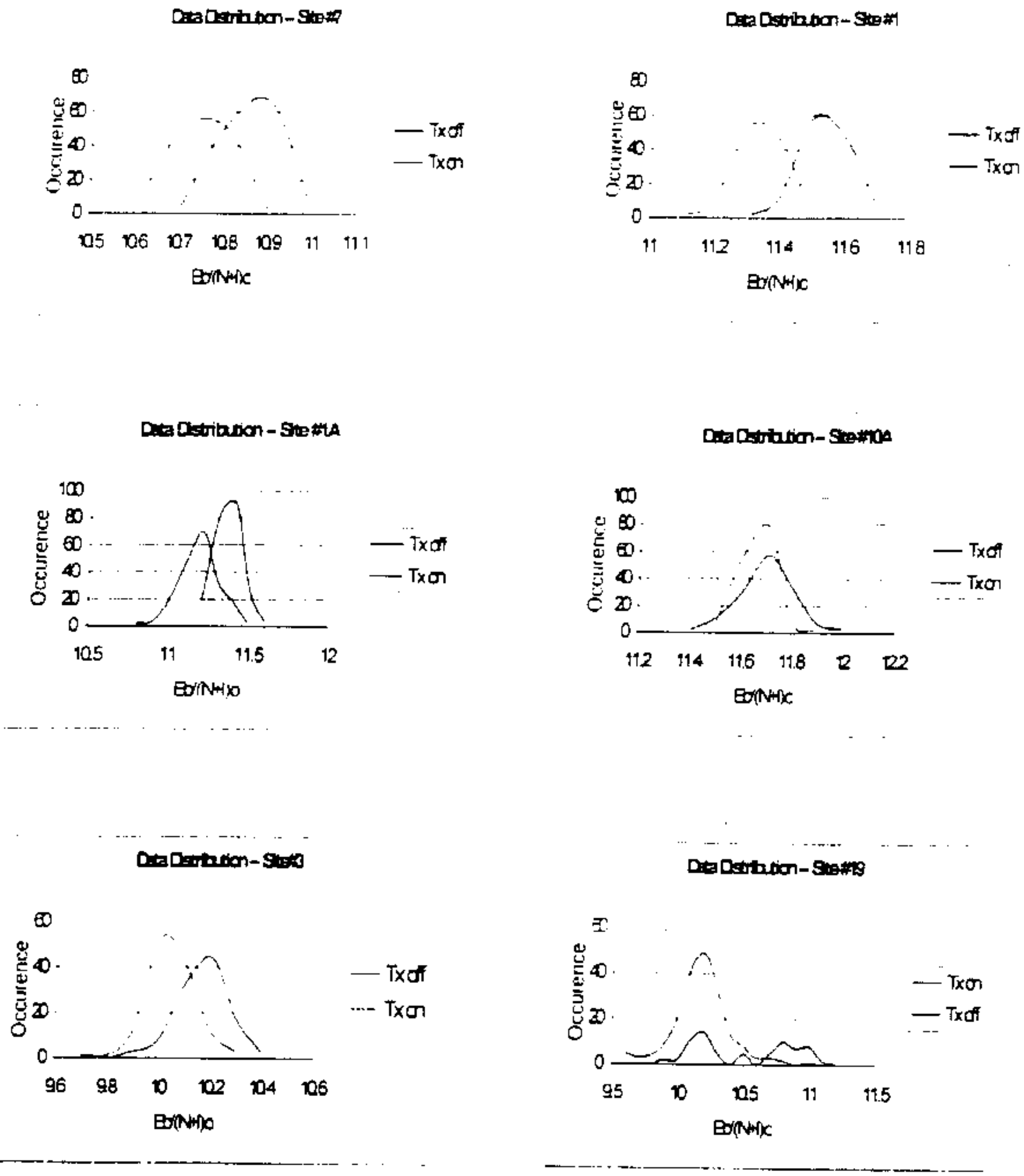


Figure 2: Distribution of test data for the six sites

anomaly is not caused by Northpoint interference. there is enough evidence to support this conclusion:

1. This site is considerably far from the transmitter and the Northpoint signal intensity is the lowest for this site among all the tested sites(-123 dBm/MHz as seen from Table 1).
2. The received power difference far exceeds the compensating difference in the DBS antenna side-lobe gain[17].
3. There was no other report such as loss of sync or other receiver problems.
4. Double humped shape in the distribution of measured data is generally caused by inconsistent data due to intermittent setup.
5. Most importantly, the distribution mean suggests that the mean difference is negative, this is not meaningful since it implies DBS reception gets better when Northpoint signal is ON.

We believe these reasons are sufficient to pronounce this set of data as simply bad data and exclude it from further analysis.

Table 3: Data Analysis Summary

Site #	Distance from TX Km	d_m (dB)	Variance s^2	t	95% Confidence Interval (+/-)
7	1.38	0.098558	0.003589	16.7	0.011514
1	0.17	0.209469	0.010460	21.7	0.018858
1A	0.29	0.177732	0.021175	17.0	0.020477
10A	0.42	0.036099	0.015508	03.4	0.020555
3	1.14	0.119167	0.019359	8.9	0.026241

We will now examine the result of data analysis and make the following observations:

1. Considering our critical value for t, 1.96 for 95% confidence interval, we note that the case for site #10A is not very strong. Note also that the interval is quite wide (+/-0.020555), considering the small difference between the sample means (0.036099). This simply indicates that the estimate for this particular set of data is not accurate enough.

[17] +6 dB side lobe difference vs -15 dB power difference, compared to the closest site at the River Place.

2. A second glance at the mean difference for site 10A reveals a marked inconsistency with the general and expected trend of results for increasing distance (see the order 1>1A >10A >3 >7)

3. Due to the above uncertainties, it is reasonable to discard the result for 10A. if we do so, then there is a logical correspondence between the distance from Northpoint transmitter and the mean difference.

4. The above finding is quite interesting since it suggests that there is little evidence to indicate that other propagation phenomena such as diffused and multipath reflections will have an important effect on Northpoint interference to DBS. We make this conclusion because the sites under consideration had profoundly different characteristics with respect to their immediate surroundings.

5. Our statistical calculation suggests that the interference from Northpoint test transmitter to the DBS consumer located at the site #1, which was only 0.17 Km away from NP experimental transmitter will not exceed 0.23 dB on average with 95% confidence[18].

6. The above level of interference is insignificant considering the DBS clear air margin of 6 to 7 dB[19] with nominal received Eb/No of 11.6 dB, the equivalent Eb/Io would be 24 dB[20].

Conclusion:

We have provided a straightforward methodology and procedure for precise characterization of Northpoint small interference to DBS services. This technique was used to analyze six cases of field measurements in Washington DC with various distances, all less than one Km, from Northpoint experimental transmitter. Our analysis shows that for test receiver at a distance of 0.17 Km from Northpoint experimental transmitter, measured degradation of received Eb/No is less than 0.23 dB with 95% confidence. Further, This reduction corresponds to a C/I of 24 dB under the test conditions. For general applicability, these figures can be scaled to other link conditions in conjunction with the DBS link budget and interpreted with respect to the link availability in terms of

[18] Reference Table 3, (0.209469+0.018858).
[19] Link margin reported by the test receiver was nominally 6.8 dB. Eb/No for QPSK modulation with ¾ inner code concatenated with Reed-Solomon RS(294, 188, 8) is about 5.5 dB for Quasi Error Free (QEF) operation.
[20] Output error measurement data indicated virtually no error (default value of 10^-25).

percentage of time and places. It is our opinion that for this level of interference the impact on the DBS services is negligible in all weather conditions. It should also be noted that there is no evidence in the analysis results to indicate that other propagation phenomena such as diffused and multipath reflections will have an important effect on Northpoint interference to DBS. We make this conclusion because the sites under consideration had profoundly different characteristics with respect to their immediate surroundings yet the analysis result did not indicate this to be a difference.

Acknowledgment:

This project provided an opportunity to work with Northpoint technical staff and Broadwave USA management during their tests which was performed in the months of August and September of 1999 in Washington DC. We observed desire to use due diligence in safeguarding the DBS customers. At the same time, we found them to have incomparable passion for bringing innovative alternatives to the consumer.

Finally, we would like to thank Northpoint, D.C. Engineering staff and Dr. Darrell Word for their support in providing background information and performing field measurements to provide data for this analysis