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FEDERAL COMMUNICATIONS COMMISSION
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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
Satellite Delivery of Network Signals	)	CS Docket No. 98-201
To Unserved Households for	)	RM No. 9335
Purposes of the Satellite Home Viewer Act	)	RM No. 9345
	)	
	)	
	)	
	)	
Part 73 Definition and Measurement	)	
Of Signals of Grade B Intensity	)	
	)	

Response to Notice of Proposed Rule Making

Introduction

In the instant proceeding, the Federal Communications Commission (FCC) asks for comments relating to petitions for rulemaking filed by the National Rural Telecommunications Cooperative (NRTC) and EchoStar Communications Corporation (EchoStar). The petitions address the methods for determining whether a household is "unserved" by local network affiliated television broadcast stations for purposes of the 1988 Satellite Home Viewer Act (SHVA).

These comments are being offered for the simple reason that I believe that my background of experience has applicability to the discussion at hand. My qualifications are a matter of record at the FCC. I have received no remuneration whatsoever for this effort.

The Satellite Home Viewer Act Test of "Unserved Household"

In the Satellite Home Viewer Act, Congress granted a limited exception to the programming copyrights of television networks and their affiliate stations that allows reception of network programming via direct-to-home (DTH) satellite service "to persons who reside in unserved households." The term "unserved household" is defined by SHVA to mean a household that --

> "(A) Cannot receive, through the use of a conventional outdoor rooftop receiving antenna, an over-the-air signal of grade B intensity (as defined by the Federal Communications Commission) of a primary network station affiliated with that network, and
>
> (B) Has not, within 90 days before the date on which that household subscribes, either initially or on renewal, received secondary transmissions by a satellite carrier of a

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network station affiliated with that network, subscribed to a cable system that provides the signal of a primary network station affiliated with that network."

In its Notice, the FCC either seeks common on or asks questions regarding at least sixty topics. In these comments, I will attempt to respond to each of the Commission's queries. In order to make it clear just which of the many items is being discussed, I have preceded each response with an appropriate except from the Notice, along with an identification of the pertinent paragraph, as identified in the Notice. For example, @NPRM ¶17 indicates that the following excerpt and response refer to paragraph 17 of the Notice of Proposed Rule Making. Skeletal text, excerpted from the Notice, appears in bold type.

SHVA Definition of "Unserved Household" Parsed to Plain English

Of the above two-paragraph definition of the term "unserved household", the second is clear enough, and need not be the subject of further discussion. The impact of the first paragraph, however, has been the subject of much discussion. It seems reasonable that parsing that paragraph into plain English would be a good approach toward understanding its essential meaning. Meanings of individual words of particular importance as found in Merriam Webster's Collegiate Dictionary, Tenth Edition, are quoted, below. (Obvious meanings of certain words are not in quotes.)

Cannot - (negation of auxiliary verb) implies inability, not a lack of desire, to accomplish something. In context, there may be many reasons why a given householder cannot receive a television signal; the residence may be in a high-rise building where rooftop antennas are not allowed, or there may be zoning ordinances against such antennas.

Receive - (intransitive verb) " 3: to convert incoming radio waves into *perceptible* signals"

Perceptible - (adjective) ": capable of being perceived, especially by the senses <a ~ change in her tone><the light became increasingly ~> SYNONYMS PERCEPTIBLE, SENSIBLE, PALPABLE, TANGIBLE, APPRECIABLE, PONDERABLE ... PERCEPTIBLE applies to what can be discerned by the senses often to a minimal extent <a perceptible difference in sound to a careful listener> . . ."

Conventional - (adjective) " 2 b: lacking originality or individuality: TRITE c (1): ordinary; commonplace"

Antenna - (noun) " 2: a usually metallic device (as a rod or wire) for radiating or receiving radio waves"

Signal - (noun) " 4 b: the sound or image conveyed in telegraphy, radio, radar, or television; c: a detectable physical quantity or impulse (as a voltage, current, or

magnetic field strength) by which messages or information can be transmitted"

Intensity - (noun) " 2: the magnitude of a quantity (as force or energy) per unit (as of area, charge, mass, or time)"

Clearly, the SHVA recognizes that the goal here is a picture (with accompanying sound) and not the quantification of a signal strength. Nowhere does SHVA use such terms as "a measured signal strength."

The FCC specifies minimum required field strength values for three service contours: City Grade, Grade A and Grade B. The required field strength for each of those contours is ultimately based on received picture quality. That picture quality, which seems unlikely to be acceptable in today's environment, was only marginally acceptable to half of the test observers who participated in the extensive viewer-satisfaction testing performed by the Television Allocations Study Organization (TASO) during the late 1950's. TASO developed a six-level picture quality rating system, ranging from Grade One ("Excellent - The picture is of extremely high quality, as good as you could desire.") through Grade Three ("Marginal - The picture is of acceptable quality. Interference is not objectionable.") To Grade 6 ("Unusable - The picture is so bad that you could not watch It.").

The FCC based its channel allotment planning factors on a signal to noise-and-interference ratio of 30.0 dB, which corresponds closely to TASO Grade 3 (See Development of Grade B Planning Factors, herein). Keeping in mind that Grade 3 corresponds to a picture that was only barely acceptable to half the viewers almost four decades ago, before there was much of a television presence in this country, it would seem unlikely that a picture of that quality would be acceptable today. It is suggested that a TASO Grade 2 picture ("Fine - The picture is of high quality providing enjoyable viewing. Interference is perceptible.") Might be a more appropriate present day goal. TASO Grade 2 represents a signal-to-noise-and-interference ratio of about 36.0 dB.

What is a *conventional outdoor rooftop-receiving antenna*? The words outdoor and rooftop are clear enough, but *conventional* merits further consideration. As is noted @NPRM ¶40 Response, the genre on which the FCC based its channel allotment planning factors were fairly elaborate antennas, having at least four elements. As is also discussed, appreciable increases in antenna gains, greater than those assumed in the FCC's planning factors, are probably not practical.

The term *over-the-air* can reasonably be taken to mean not via cable or other direct connection.

SHVA's reference to *Grade B intensity (as defined by the Federal Communications Commission)* defines the minimum signal strength that may be considered. Households at which the signal strength is less than Grade B are, by definition, unserved.

Primary can be taken to mean the main transmission facility of a network affiliate station, and not translators or satellite TV stations.

The SHVA Unserved Household Test, As Translated

Thus, SHVA's reference to Grade B intensity immediately qualifies as unserved those households in locations where the actual signal strength of network affiliate station(s) is less than that specified by FCC in Section 73.683 of the FCC Rules.

Further, SHVA's reference to the Grade B standard, the development of which flows from the requirement that the received picture be acceptable to the median viewer, qualifies as unserved those households, regardless of signal strength, that cannot receive an acceptable picture.

A Note Regarding Television Reception Terminology

In the case at hand, *intensity* refers to signal strength, described in terms of Volts (or microVolts) per meter. An *antenna* is a device that transforms the energy in a passing radio wave into a *voltage*, which, when applied to a *transmission line*, causes a *current* to flow in the transmission line. The transmission line is connected to a *receiver*, which is according to Merriam Webster's Collegiate Dictionary is: "1 d: a device for converting signals (as electromagnetic waves) into audio or visual form; as (1): a device in a telephone for converting electrical impulses or varying current into sound (2): a radio receiver with a tuner and an amplifier on one chassis". Provided that the *receiver*, *transmission line*, and *antenna* are all properly matched (that is, designed so as to work correctly with one another) the received signal *power* will be transferred to the receiver with a minimum of decrease in its strength (*attenuation*).

Unfortunately, the receiver itself can never be perfect; it creates internal set noise, which appears on the picture screen as "snow" and there may be other noise, received by the antenna and delivered to the receiver, due to electrical appliances in the neighborhood ("urban noise"). Finally, other television stations may create objectionable *co- or adjacent-channel* interference.

Development of Grade B Planning Factors

The actual values assumed by the FCC for various important parameters in their derivation of the values for Grade B were discussed in "*Understanding Television's Grade A and Grade B Service Contours*', by R. A. O'Connor (IEEE Transactions on Broadcasting, Volume BC-14, Number 4, December 1968). The derivation of the Grade B values is as follows:

Parameter	Sign	Channels 2 to 6	Channels 7 to 13	Channels 14 to 83
Nt (dBu)	+	7	7	7
Ns (dB)	+	12	12	15
Snr (dB)	+	30	30	30
Kd (dB)	-	3	-6	-16
G (dB)	-	6	6	13
L (dB)	+	1	2	5
ΔT 90% (dB)	+	6	5	4
ΔL 50% (dB)	+	0	0	0
Grade B Values		47 dBu	56 dBu	64 dBu

Where:

Nt is the inherent thermal noise generated across the terminals of an ideal receiver. Thermal noise is a function of temperature, bandwidth, and circuit resistance. Assuming 300-Ohm input impedance for a TV receiver having a bandwidth of 4.0 MHz and room temperature (290 Degrees, Kelvin), thermal noise is 2.19 uV, or about 7 dBu.

Ns is a measure of how much greater the actual set noise is relative to thermal noise (Nt). The above values are those that the FCC assumed to be typical of TV receivers in the late 1950's.

Snr is the desired signal-to-noise ratio. The FCC chose to use a 30 dB ratio, which corresponds closely to a TASO Grade 3 or "passable", which is described as: "The picture is of acceptable quality: Interference is not objectionable." That, of course, was the judgement of non-technical observers in a study completed almost 50 years ago.

Kd is the "dipole factor", the conversion factor between field strength (measured in terms of volts per meter) and volts across the output terminals of the antenna.

G is the assumed gain of a typical receiving antenna. The FCC assumptions (6 dB at VHF and 13 dB at UHF) imply fairly elaborate antenna designs.

L is the assumed transmission line loss.

ΔT is the time-variability factor. Grade B and Grade A contour signal strength specifications are based on a 90% time-availability factor.

ΔL is the location-variability factor. The Grade B signal strength values are based on a 50% requirement.

The corresponding development of required signal strength for Grade A (70% of the locations, as opposed to 50% for Grade B) results in values of 54, 64, and 74 dBu for Channels 2-6, Channels 7-13 and

UHF, respectively. There is, however, the interesting footnote that an additional 14 dB of signal strength is required to overcome urban noise at low-VHF (Channels 2-6) and 7 dB at high-VHF (Channels 7-13).

Responses to Specific NPRM Queries

@NPRM ¶17: First, we seek comment on the Commission's authority to address the issues raised in the court decisions and the NRTC and EchoStar petitions.

Response: I do not have access to the complete texts of the above-referenced cases. However, as a general matter, the FCC is the expert agency on the subject of television broadcast. Thereby, it would appear that no agency is better qualified than the FCC in this matter.

@NPRM ¶17: Second, we seek comment on changing the definition of Grade B intensity so that truly unserved households can be better identified.

Response: Having examined the plain-English meaning of the SHVA definition of "unserved household", I am of the opinion that the Act's use of the Grade B contour signal strength as being a (minimum) threshold value is both correct and proper. I urge that the FCC and the broadcast and satellite industries move on from the present fixation on signal strength to a consideration of received picture quality.

@NPRM ¶17: Third, we seek comment on endorsing or developing a methodology for accurately predicting whether an individual household is able to receive a signal of Grade B intensity.

Response: I strongly support the prediction idea, but I have reservations about the notion of the FCC being involved in the development of such a capability. The Commission's processes, while sound and appropriate from a democratic perspective, are terribly slow and cumbersome. The DTH industry, unfortunately, is facing a death sentence in early 1999 and simply does not have time to waste.

Therefore, it would seem that a reasonable approach would be that any interested party(s) develop predictive models, either independently or cooperatively. Based on staff expertise and comments received in this enquiry, the FCC may be able to formulate guidelines for the performance of such models.

The FCC should provide an administrative mechanism for the resolution of contested cases. A provision for (and definition of) a testing procedure is properly a FCC responsibility. Also, there should be a "loser pays" provision, which would keep the number of contested cases at a minimum as well as serve as a motivation for the continual improvement of the predictive model(s).

@NPRM ¶17: Fourth, we seek comment on developing an easy-to-use and inexpensive method for testing the strength of a broadcast network signal at an individual household.

I believe that lack of adequate signal strength (within the Grade B contour, as predicted in accordance with Section 73.684 of the FCC Rules), will be found to be the causative factor of poor reception in only a small minority of the cases. Other factors, such as multi-path reception ("ghosts"), urban noise, and interference will found to be the dominant reasons for unacceptable picture quality. Therefore, I urge that the FCC focus on techniques by which picture quality can be quantitatively determined, rather than on the very difficult signal strength measurement task.

@NPRM ¶20: First, we seek comment on whether Congress "froze" the definition of a signal of Grade B intensity for purposes of the SHVA when it adopted the Act in 1988. That is, if the Commission were to revise the definition as a general matter, would the definition nevertheless remain unchanged for the purposes of the SHVA? We tentatively conclude that Congress did not "freeze" the definition of a signal of Grade B intensity for SHVA purposes in 1988 and seek comment on this tentative conclusion.

Response: I am of the opinion that there is no need to change the definition of Grade B signal strength value; therefore, this query is moot.

@NPRM ¶22: Second, we seek comment on whether the Commission has the authority to revise its Grade B rules specifically for the purposes of the SHVA.

Response: I have no opinion on this matter.

@NPRM ¶23: Third, we seek comment on whether the Commission has the authority to develop a model for predicting whether an individual household can receive a signal of Grade B intensity for purposes of the SHVA.

Response: Certainly, the Commission has the authority to develop administrative tools, including predictive models, which contribute to the discharge of its responsibilities of spectrum administration. However, as discussed above, I have concerns about the FCC undertaking the development of such a model; I believe that industry should bear that resonsibility, perhaps with some oversight by the Commission.

@NPRM ¶25: Fourth, we seek comment on our conclusion that the Commission's authority to define a signal of Grade B intensity reasonably includes the authority to adopt a method of measuring signal intensity at an individual household.

Response: Without a doubt, for the reason as stated in response to NPRM ¶23, above.

@NPRM ¶26: (We) seek comment on the general question of what other non-SHVA rules or policies might be implicated by the changes that are discussed below.

Response: Because I see no need for the FCC to make <u>any</u> changes in its rules or in its policies in regard to the SHVA, it would appear that there need be no impact whatsoever on other non-SHVA rules and policies.

@NPRM ¶27: Has what constitutes a "conventional outdoor rooftop receiving antenna" and the concept of the quality of service that viewers consider acceptable changed since the Commission adopted the Grade B signal strength levels in the 1950s?

Response: As is discussed @NPRM ¶, the Commission's television channel allotment planning factors assumed antenna gains of 6 dB at VHF and 13 dB at UHF, which implies fairly elaborate designs, having at least four elements. Significant improvements in antenna gain would result in much larger antennas, to such an extent that it is doubtful whether homeowners would find them acceptable.

I do believe that the concept of quality of service has changed during the forty-eight years that have passed since viewer acceptance tests were conducted by the Television Allocations Study Organization (TASO). (Half of the observations were of monochrome pictures!) The FCC's channel allotment planning factors were based on a 30 dB signal to noise and interference ratio, which corresponds closely to TASO Grade 3: "Passable - The Picture is of acceptable quality. Interference is not objectionable".

I suggest that the modern median viewer would consider a TASO Grade 2 picture ("The picture is of high quality providing enjoyable viewing. Interference is perceptible") to be the minimum acceptable quality. TASO Grade 2 corresponds to a signal to noise and interference ratio of approximately 36 dB.

@NPRM ¶27: We welcome comments, supported by evidence, regarding any claimed changes to the assumptions made in deriving the Grade B signal intensity.

Response: It is important to recognize that the term "Grade B" refers to a signal strength contour, an area prediction. The Commission's values have served well for decades and I am not aware of any persuasive data that suggests that those assumptions are in urgent need of modification. However, consideration should be given to increasing the signal to noise, distortion, and interference parameter from 30 to 36 dB in the limited context of the SHVA test of "unserved'. As has been stated, I base that suggestion on the thought that the modern (median) viewer probably is more demanding with respect to picture quality than was the case in 1958, when the original tests were conducted.

@NPRM ¶28: We invite comments on all the factors that determine the Grade B signal intensity.

Response: See **@NPRM ¶27 Response, above.**

@NPRM ¶28: We also seek comment on whether changes to the current intensity values would have a detrimental effect on network-affiliate relationships and localism, as well as other Commission rules that involve the current Grade B standard.

Response: I have no expert knowledge in this matter.

@NPRM ¶32: We seek comment on whether it would be appropriate to consider changing the location and time variability percentages.

Response: Again, the existing parameters have served well for decades, and nothing in the context of the instant proceeding would seem to suggest an overwhelming need for change. After all, the entire concept of service contours is to indicate a general area in which acceptable reception is likely.

Increasing the location and time variability percentages only serves to indicate the possibility of poor reception. The question of whether a given household is expected to have adequate reception is properly left to some other predictive process.

@NPRM ¶32: We also seek comment on whether such changes should be incorporated into the signal intensity values or the predictive model.

Response: The statistics regarding probability of service should be built into the predictive model. As has been stated, factors other than signal strength will probably be found to be the major causes of unacceptable reception within the Grade B contour, as predicted in accordance with Section 73.684 of the Rules.

@NPRM ¶33: We seek comment on the application of these models in the SHVA context.

Response: I believe it to be appropriate to use models other than the contour prediction model described in Section 73.684 of the FCC Rules to the purpose of predicting whether individual households are "unserved". The FCC contour prediction model was never intended for any such use.

@NPRM ¶33: We tentatively conclude that the Commission's traditional predictive methodology for determining a Grade B contour, outlined in Section 73.684 of the Commission's rules, is insufficient for predicting signal strength at individual households. We seek comment on this tentative conclusion.

Response: The Commission's conclusion is, without doubt, correct. The signal strength contour concept was never intended to address the question of reception at individual households.

@NPRM ¶34: We propose that the Longley-Rice propagation model, as implemented for DTV, be used to refine the Grade B service prediction for the purpose of SHVA determinations ... We seek comment generally on this proposal, as well as specifically on the following questions.

Response: First, it should be noted that the Longley-Rice model, as implemented to DTV, was used to predict signal strength values only within the area inside the (analog NTSC) Grade B contour as predicted by the model set forth in Section 73.684 of the Rules.

The Longley-Rice propagation model, as implemented for DTV, is likely to be a worse predictor of service at a given household than is the FCC model set forth in Section 73.684 of the Rules. (Refer to Exhibit A, attached, which includes comparisons of the performance of Longley-Rice (with and without consideration of morphology) and that of the FCC's Carey model, which corresponds to the model described in Section 73.684.)

I am of the opinion that the Longley-Rice model, with adjustment for the effects of surface clutter (morphology), is the best starting point that is presently available in the public domain. Even though I personally have developed an algorithm, based on extensive measurement data, to adjust the model for these effects, I do not assert proprietorship of that concept. Indeed, others have published morphology adjustment values that are in close agreement with my own.

@NPRM ¶34: Should consideration of co-channel and adjacent-channel interference as implemented for DTV be part of the methodology used for SHVA purposes?

Response: Yes, co-channel and adjacent-channel interference should be considered. However, I suggest that the signal strength prediction method set forth in Section 73.684 of the Rules would perform at least as well as would the Longley-Rice model, particularly if the latter model were operated without morphology corrections.

@NPRM ¶34: Is it necessary to prescribe how accurately receive location coordinates are specified?

Response: I believe receive locations, as geo-coded from street address, are sufficiently accurate. After all, the resolution of the best terrain data, which inevitably enters into the precision of our ability to predict the probability of acceptable reception, is only 3 arc-sections, which represents a rectangle of about 90 meters north-south by about 70 meters east-west. Even a geo-coding tool as readily available as the "Streets 98" program that is supplied as part of the Microsoft Window 98 software gives results that are adequate relative to the terrain data resolution.

@NPRM ¶34: Can Longley-Rice be modified to increase the probability of identifying served and unserved households more accurately? How?

Response: Yes, the Longley-Rice model can be so modified. In particular, it can be used to determine areas that do not have direct line-of-sight paths to the transmitting antenna. Once such an area has been identified, it is possible to cause the model to examine the horizon around the "hole" to detect the presence of scattering objects, such as tall vegetation or buildings, based on an associated morphology database.

Further, the model can also be linked to the U.S. Census to determine the population density in the vicinity of each prediction point; urban noise being known to increase with increasing population density.

@NPRM ¶34: What are the predictive factors that are missing in the current Longley-Rice model?

Response: The current Longley-Rice model is oblivious to the matter of reception quality. The above response addresses some of the improvements that could be made in the application of the model.

@NPRM ¶34: Can Longley-Rice reasonably be modified to account for all these factors?

Response: Yes, it can be so modified. In fact, a computer implementation incorporating those and other modifications is well along toward completion.

@NPRM ¶34: What effect would incorporation of these additional factors have on the cost and practicality of the Longley-Rice methodology?

Response: First, costs of improving the predictions of the Longley-Rice model (or any other methodology, for that matter) should lie with industry and not with the public. I am confident that the cost per unit household can be made acceptable and that the approach is practical.

@NPRM ¶34: Can Longley-Rice or a modified version of Longley-Rice be used in conjunction with a commercially available geocoding process to provide a workable predictive model for satellite providers, broadcasters, and consumers to use for determining whether a given subscriber is presumed to be unserved?

Response: The direct answer to this question is: Yes, without doubt. However, provision should be made to allow the use of more precise predictive models if and when they become available.

@NPRM ¶34: We seek comment on whether such currently available approaches are working well for the industries and consumers.

Response: Based on years of experience with the model, I believe that the Longley-Rice model, with correction for the effects of morphology, works quite well as a signal strength predictor. I have no knowledge of anyone's having used the model as a predictor of the probability of acceptable television reception at individual households.

@NPRM ¶35: Is there a predictive methodology that will increase the probability that unserved households will be more accurately identified (e.g., by taking into account interference)?

Response: Interference from other television stations should be taken into account. I do suggest, however, that the prediction method set forth in Section 73.684 of the Rules would be as appropriate for this purpose as is the Longely-Rice model, even with morphology correction.

@NPRM ¶35: What is that methodology?

Response: See the immediately preceding response.

@NPRM ¶35: For either a version of the Longley-Rice model or another alternative methodology, how might parties use a new predictive model?

Response: A query-response system can be implemented on PC level machines. I envision that a database, updated periodically, could be distributed to interested parties on compact discs. Modern PC's can readily accommodate enough memory to hold the entire nationwide database. Query response times for such a system have to be rather rapid in view of the fact the direct-satellite-to-home business is expanding at a rate of more than a million subscribers per year.

@NPRM ¶35: Can and should the Commission endorse or develop a predictive model?

Response: No, the Commission should not undertake the development of a predictive model. First, there is no apparent reason why the public should fund an effort that is properly the responsibility of industry. Further, the Commission may not have sufficient staff resources to allot to such an effort and (as seems to be characteristic of Government) its contracting procedures are lengthy, time-consuming and do not always lead to the best possible results.

@NPRM ¶35: Should we endorse a model that already exists or endorse such a model with modifications?

Response: I agree with the FCC that the most likely existing candidate for the predictive role is the Longley-Rice model with appropriate consideration of the effects of vegetation, buildings and other surface clutter ("morphology"). It is important to recognize, however, that the specification of high values for location/time/confidence run-time parameters in the Longley-Rice model can only serve as a general indication of the possibility of poor reception. As it exists, the model is of no use in determining whether a specific household can receive a picture of acceptable quality.

As discussed above, I believe that the Longley-Rice model can be modified or enhanced to provide reasonably reliable predictions at an individual household level.

@NPRM ¶35: What are the costs associated with any of the suggested methodologies?

Response: I believe that the cost of a well-designed and implemented predictive model would be quite acceptable, on a per household basis. Furthermore, that cost should be borne by the interested party, which might be either a satellite service provider or a broadcaster.

@NPRM ¶36: In proposing a new or modified predictive model for purposes of the SHVA, we seek comment on what, if any, effects different predictive models will have on these policies, and what, if any, steps we can take to further such policies.

Response: I have no experience in policy matters and am therefore not qualified to respond to this query.

@NPRM ¶40: We seek comment on the modification of the current testing methodology or the creation of a new methodology for measuring signal strength.

Response: I am strongly of the opinion that the usual procedure, a mobile run with the receiving antenna 30 feet in the air, performed somewhere in the general vicinity of a specific household is not an acceptable determinant of signal strength at rooftop level at the subject household.

If it is deemed desirable to pursue the subject of received signal strength further, perhaps the following process would be appropriate: 1) Perform a survey of the types of, and mounting arrangements of, household rooftop television receiving antennas in use in this country. 2) Take steps to replicate a set of such antennas (but known to be in proper operating order), sufficiently large to ensure statistical accuracy. 3) Perform measurements of received power at the receiver terminals. 4) By making use of this set of "ground truth data", create a model that (accurately) predicts the probable received signal strength at other possible receiving locations.

Fortunately, there does exist a commercially available measurement set that provides accurate objective measurements of received picture quality. (A copy of materials describing the Tektronix Model VM700T NTSC Video Measurement set is attached as Exhibit B.) Among the picture parameters that can be measured by the VM700T are: frequency response, noise, variations of signal amplitude with "flat fields" (i.e., "ghosts") and many others.

Use should be made of the WM700T (or equivalent instruments, if they are available), in conjunction with the signal strength tests, as discussed above, to generate a database with a view toward improving the performance of the predictive model(s).

@NPRM ¶40: We seek comment on what qualifies as "a conventional outdoor rooftop receiving antenna.

Response: The FCC assumed certain values for receive antenna gain in their derivation of the numerical values of Grade A and Grade B signal strengths. Specifically, the assumed gains (decibels relative to a half-wave dipole or dBd) were 6 dBd at VHF and 13 dBd at UHF. There is an antenna engineering rule-of-thumb that the gain of an antenna increases about 3 dB for each doubling of the number of elements, which would indicate about a four-element antenna at VHF and perhaps bow-tie antennas in front of a screen, stacked about four high at UHF. These are not particularly simple antennas. An additional 3.0 dB or so increase in required gain would result in much larger (about twice as big), more expensive antennas than the average householder is likely to want to deal with. Further, the problems involved in determining (and characterizing the variability of) signal strength at a given location make it difficult to ensure an accuracy of better than 3.0 dB or so. In summary, feasible increases in antenna performance are not a significant factor in this proceeding.

@NPRM ¶40: Are different antennas required for different parts of the country, or as one moves farther from a television transmitter?

Response: As stated, above, the FCC's planning factors assumed fairly elaborate antennas as being typical of actual usage. Therefore, I don't see much reason to reassess those assumptions.

@NPRM ¶40: What special problems do viewers in multiple dwelling unit buildings ("MDUs") face in gaining access to a conventional outdoor rooftop television antenna?

Response: Residents of multiple-dwelling units may, in fact, not even have the right to erect (or the right of access to) outdoor rooftop antennas. In such case, a self-certification process should be a sufficient test of eligibility.

@NPRM ¶40: Should the testing methodology be different for high-rise MDUs?

Response: Because occupants of high rise buildings often do not have the right to install rooftop antennas, I suggest that a sufficient test of eligibility would be a certification, signed by the householder, that such is the case.

@NPRM ¶40: Does "conventional outdoor rooftop receiving antenna" include a rotor?

Response: I believe that the Commissions planning factors did not consider rotors. Therefore, the answer to this question is no.

@NPRM ¶40: How, if at all, should the Grade B criterion of typical of outlying or near-fringe areas influence the concept of "conventional" antenna?

Response: As stated, I believe that the FCC's assumptions remain adequate.

@NPRM ¶40: On **another note, how do we ensure the objectivity and accuracy of any signal strength test?**

Response: Objectivity basically depends on the ethics of the person performing the test. I don't know that it is even possible to ensure objectivity by means of an administrative process, such as might be available to the Commission.

With respect to the accuracy of signal strength testing, I suggest that this is a very difficult, many-faceted problem that should be addressed, but in a more general context that the case at hand.

@NPRM ¶40: How do we do so without making the test more difficult, impractical, or expensive?

Response: As suggested, above, my experience has been that there is no quick, simple way of obtaining reliable signal strength measurement data. I wish that I could make a suggestion here, but I can't.

@NPRM ¶40: How should antenna height be measured?

Response: There are inexpensive, handheld devices that determine the height of remote objects.

@NPRM ¶40: Should antenna height be set at 30 feet, should it be five feet above the roof, or something else?

Response: A ten-foot or so difference in antenna height really doesn't make much difference because of the variability of observed signal strength with time (both short term and long term), location, airplane and vehicular traffic in the vicinity, tree leaves fluttering in the breeze and so on, ad infinitum. Interestingly, because houses are almost always immersed in surface clutter, such as other houses, trees, and so on, there will be rapid variations of signal strength within short distances (that is, over paths of just a wavelength or so). These variations occur in both the horizontal and in the vertical dimensions. In other words, there is no means of accurately predicting the behavior of signal strength with small changes of antenna height so long as the antenna is immersed in the surrounding clutter. In other words, there really is no single "height-gain" function for antennas in clutter.

@NPRM ¶40: Should the measurement be related to the placement of the satellite receiver in situations where the satellite and local signal antennas are integrated?

Response: The measurement should be related to wherever reception of local signals is being attempted.

@NPRM ¶40: If antenna designs are improved over those historically available so that the definition of "conventional" changes, how should that be accommodated in the measurement process?

Response: As is discussed elsewhere in these comments, I am of the opinion that antenna designs that are both significant improvements over available models and are acceptable to households are not likely to come about.

@NPRM ¶40: How should we account for the challenges of raising a rooftop antenna in multiple dwelling units?

Response: I suggest that a certification by the householder that the residence is in a building (multiple dwelling or not) in which the householder does not have the right to erect an individual television receiving antenna be a sufficient determinant of eligibility.

@NPRM ¶40: How should the test account for rotation, or lack of rotation, of antennas which receive the signals of several stations?

Response: I don't know that signal strength measurements can be made to account for multiple direction of reception problems, such as is posed in this question.

@NPRM ¶40: What type and calibration of measurement equipment is needed?

Response: My first recommendation on the subject of signal strength measurement at the individual household level in the present context is to avoid it if at all possible. The process is too tedious, too physically dangerous to those persons performing the measurements, too ambiguous, and too expensive to be a very useful tool. My second recommendation is that there be created a model designed to predict those locations that would likely have poor reception. In order to reach a reasonable level of respectability, the model should be tested extensively against field observations.

@NPRM ¶40: **How can the process account for the variations of signal level over the course of a day or with seasonal changes?**

Response: It can't, other than through statistical estimates. The problem with doing so is that there is no way of knowing where, on the distribution continuum, the signal strength was at the time of observation. Simplistically, one could take the approach of observing the signal over a period time. However, that might take hours, days, or even years. For example, significant increases in received signal strength can occur when the leaves fall of the trees in the fall, or long-term changes in the atmosphere might be important.

@NPRM ¶41: We seek comment on whether the lack of an established methodology for measuring Grade B signal intensity at individual households has hampered the effective functioning of the SHVA.

Response: As has been set forth at length and in detail, there is more to the subject of eligibility than signal strength. In fact, it is my opinion that it will evolve that there are many more households within the Grade B contour (predicted in accordance with Section 73.684 of the Rules) that are eligible for service due to interference (including that due to noise, multi-path reception and other TV stations) than are eligible because of a lack of signal.

@NPRM ¶41: We seek comment on whether parties are making use of the "loser pays" mechanism. If they are not, why not? Can and should we establish rules or policies that will facilitate their ability to do so? We also seek comment on whether the loser pays mechanism, combined with a predictive model that would minimize the need for individual testing in most cases, would facilitate the effective functioning of the Act.

Response: With respect to the question of whether, and to what extent, parties are making use of the "loser pays" mechanism, I have no information.

I believe that the Commission can and should establish policies (rather than rules) that will facilitate the "loser pays" concept. I suggest policy rather than rule making because of the lengthy, cumbersome process that the latter process at the FCC involves.

I believe that a predictive model, in conjunction with a "loser pays" provision, would minimize the overall burden of the process of determining eligibility of a given household. Even if the predictive model were correct only 50% of the time, it would probably not be prudent to continue contesting determinations when there existed even a one-in-two chance of being wrong and having to pay.

@NPRM ¶42: We also seek comment on whether we can and should adopt a procedure similar to the SHVA's expired transitional "loser pays" mechanism.

Response: I believe that a "loser pays" procedure is a good idea and that it is one of the few areas regarding the SHVA in which the FCC should take a proactive approach. Such a provision should greatly decrease the number of contested cases.

@NPRM ¶42: Does that provision represent a workable system for allocating burdens of proof, and appropriate incentives to challenge a presumptive rule, in determining who is and who is not an unserved household?

Response: I believe that it does, and failure to provide such a provision would, of itself, increase the burdens upon both the DTH and the television broadcast industries.

@NPRM ¶42: Are there other mechanisms that can better serve the purposes of the SHVA?
@NPRM ¶42: Are there additional actions the Commission can and should take to make enforcement of the SHVA more effective?

Response: None that are presently known to me.

@NPRM ¶43: Finally, we seek comment on the prospect that the industry will develop "local-into-local" technology to serve every community. If Congress adopted a local-into-local extension of the compulsory license, how would such a change affect the need for, and viability of, the proposals in this rulemaking? We seek comment on the feasibility -- particularly the technical feasibility -- of a local-into-local option and on a time frame for implementing this possible solution to the demands for satellite delivery of network station signals.

Response: I can offer no comments on this matter.

An Observation Regarding the NRTC Petition

With respect to the NRTC proposal for a new definition of "unserved" that includes all households located outside a Grade B contour encompassing a geographic area in which 100 percent of the population receives over-the-air coverage by network affiliates 100 percent of the time using readily available, affordable receiving equipment, it should be noted that such a definition would reduce that station's service area to zero.

Respectfully submitted,

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Exhibit A
Overview of Radiowave Propagation Prediction Modeling and Comparison of Performance of Models

An Introduction to the Concept of Modeling

In the introduction to "A guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode" (NTIA report 820100, April 1982), authors Hufford, Longley, and Kissick observe:

> "Radio propagation in a terrestrial environment is an enigmatic phenomenon whose properties are difficult to predict. This is particularly true at VHF, UHF and SHF where the clutter of hills, trees and houses and the ever-changing atmosphere provide scatting obstacles of the same order of magnitude as the wavelength. The engineer who is called upon to design radio equipment and radio systems does not have available any precise way of knowing what the characteristics of the propagation channel will be nor, therefore, how it will affect operations. Instead, the engineer must be content with one or more models of radio propagation - i.e., with techniques or rules of thumb that attempt to describe how the physical world affects the flow of electromagnetic energy."

Authors Hufford, Longley, and Kissick made this observation from a position of eminent authority; all three were (Ms. Longley is now deceased) professionals of international reputation who devoted their careers to the study of radiowave propagation at the Boulder, Colorado, laboratories of the U.S. Department of Commerce. Ms. Longley, for example, co-authored the widely used Longley-Rice signal prediction model.

Later, in the same publication, the authors make the following very useful observation:

> "Most radio propagation models, especially the general purpose ones, can be characterized as being either a "point-to-point" model or an "area prediction" model. The difference is that a point-to-point model demands detailed information about the particular propagation path involved while an area prediction model requires little information and, indeed, may not even require that there be a particular path."

Brief Descriptions of Widely Recognized Models

Examples of area prediction models include the very straightforward models ones are prescribed by the Federal Communications Commission ("the FCC") for use in the FM and Television broadcast services (Sections 73.313 and 73.684 of the FCC Rules) and for the mobile radio services (Section 22.504).

The FCC's models require information regarding only the type of service (FM, TV or Mobile Radio), the frequency band, the effective radiated power ("ERP"), and the height of the transmitting antenna radiation center above the average of the surrounding terrain. Based on these data, the predicted signal strength can be determined through reference to one of a series of graphical figures ("curves") that are contained in the Rules.

Both the broadcast and the land-mobile ("Carey") curves are based on recommendations published by the International Radio Consultative Committee ("CCIR") of the International Telecommunications Union ("ITU"). Certain adjustments to the CCIR recommendations were made to adjust the models to conform to an empirical analysis of field strength measurement data. Thus, the FCC models can be correctly characterized as being roughly representative of the median extent of the effects of such surface clutter as then existed at the time signal measurements were performed along the paths for which data was used in the development of those models.

Because the goal of the FCC is to provide a straightforward method of predicting average (or median) cases, the approach taken by the commission in the design of its prediction model is reasonable and provides useful results, at least from the spectrum administrator's perspective.

An elaborate area-prediction propagation model was published by Okumura (Y. Okumura, E. Ohmori, T. Kawano, and K. Fukuda (1968), *Field Strength and It's Variability in VHF and UHF Land Mobile Radio Service*, rev. Tokyo Electrical Communications Laboratory.). The Okumura model is based on the careful analysis of a large set of signal strength measurement data, taken in Japan, in a wide variety of terrain and vegetation and urban clutter environments at six different frequencies in the VHF and UHF bands. The model includes signal strength prediction graphs for bands centered at 150, 450, 900, and 1,500 MHz, based on propagation conditions found to be typical of densely urbanized areas (such as Tokyo). Corrections are provided for less dense environments, such as "Sub-urban" and "Open". (The "Open" classification is, to American readers, rather quaintly characterized as including "rice fields").

Additional corrections to the basic "Okumura" curves are provided for different types of terrain, degrees of terrain ruggedness, slope of the land, land vs. over water paths and so

on, to such an extent that practical computer implementation of the model becomes difficult.

Possibly the most important advance made by the Okumura model is the attempt to quantify the effects of different extents and types of urban and vegetation clutter. The differences between Urban Area and Open Area paths can be impressive. For example, at 200 MHz, the increase in signal strength for an Open Area path as compared with an Urban Area path is on the order of 20 dB.

The Okumura model also provides a factor to account for the difference in excess path attenuation as a function of the downward angle from source into the surface clutter. This, too, is an important consideration; according to the graph (Fig. 16), included in the Okumura article, a three-degree difference in the downward angle can cause a change of signal strength in excess of 20 dB. As will be discussed, similar effects were observed in actual field strength measurements, taken in locations as diverse at the San Joaquin Valley in California and the densely forested flatlands of St. Tammany Parish in Louisiana.

Hata published a computer program based on a greatly simplified version of the Okumura model. The Hata model is noted only in passing; even though it has been applied to the design of some mobile radio systems, it has no features that make it of particular interest in this discussion.

Numerous other area-prediction models have been published, both in the United States and internationally by such organizations as the International Radio Consultative Committee ("CCIR"). All, other than Okumura, are similar to the FCC models in that they produce generalized representations of the expected performance of systems that cannot be expected to provide acceptable results in each and every particular case.

Other models that attempt to provide more accurate predictions over a wider range of conditions have gained considerable recognition, including several that are closely based on procedures outlined in "National Bureau of Standards Technical Note 101, Transmission Loss Predictions for Tropospheric Communications Circuits." That volume, widely known as NBS Tech Note 101, was authored by P.L. Rice, A.G. Longley, K.A. Norton, and A.P. Barsis.

Basically, NBS Tech Note 101 is a comprehensive compilation of computational procedures that are applicable to specific steps in the over-all problem of predicting the behavior of VHF, UHF, and SHF radiowaves in the earth's atmosphere. It does not provide computer programs for performing any of the necessary calculations, nor does it treat the effects of terrain clutter (vegetation and urbanization) in other than a cursory manner.

In 1968, Anita Longley and Philip Rice, two of the four authors of NBS Tech Note 101, published a computer program that has often been characterized as being a computer implementation of Tech Note 101. ("Prediction of Tropospheric Radio Transmission Loss Over Irregular Terrain– A Computer Method, 1968, ESSA Tech. Report ERL 79-ITS 67). This program, often called "Longley-Rice", has had wide acceptance in the communications industry. It can be shown to provide impressively accurate radiowave propagation predictions in environments that closely approximate the conditions under which the data that underlie the model were observed. That is to say, the Longely-Rice model, operated in its "point-to-point" mode, often works quite well in uncluttered environments, such as the rolling grasslands of Colorado, where the model was developed.

Unfortunately, the Longley-Rice model (or any other model that does not properly consider the effects of vegetation and building clutter) can be egregiously in error in less benign environments. For example, moving the receiving antenna just a few meters into dense vegetation (such as the tall coniferous trees that cover much of the southern portion of the United States) can result in a decrease of signal strength at high-UHF channels of 28 dB or more.

Computer algorithms, originally published within the Longley-Rice program or separately by one or both of its authors, are extensively used in the TIREM program, which is another widely recognized radiowave propagation prediction program.

In summary, the Longley-Rice and the TIREM programs are closely akin, and share the deficiency that they do not address the crucially important effects of vegetation and building clutter upon the propagation of radiowaves. Both are capable of acceptable performance within certain environments, and both offer the possibility of being enhanced to address the clutter problem.

Land-use (Morphology) Considerations

The U.S. Geological Survey, Reston, Virginia, supplies computer data that use a two-digit code to characterize the type of land use or land cover ("morphology") on a regular 200 meter square grid system, for the entire United States (exclusive of parts of Alaska).

It has been found that there at least four land-use characteristics significantly affect the strength of radio signals when the receiving antenna is immersed in the surface clutter, which is almost always the case in the land-mobile and broadcast TV/FM services:

1) The type of land use/cover (morphology): dense pine forestation, for example, attenuates the signal more

than does typical desert vegetation. A computer algorithm, expressed as functions of frequency and USGS morphology codes, has been developed and has been found to closely approximate the effects of vegetation and building clutter, based on the analysis of tens of thousands of sets of field strength measurements.

2) The height of the vegetation or buildings. Estimates of the heights of different types of vegetation that are typical of St. Tammany Parish were obtained from Parish Forestry Department personnel and by direct personal observation in the course of collecting data for the comparison of models that is presented, later in this Exhibit.

3) The (downward) angle at which the signal path penetrates the surface clutter.

4) The signal frequency. A given type of clutter (vegetation or buildings) attenuates high frequencies to a greater extent than it does lower frequencies.

Basic Requirements of Radiowave Propagation Prediction Models

A competent radiowave propagation model must take certain factors into account, including:

1) Effective Radiated Power ("ERP")

Effective radiated power is the product of the power input to the transmitting antenna times the power gain of the transmitting antenna in the direction of the receiver. (Technically, circuit losses in the antenna are taken into account, but those losses are unimportant in the discussion at hand.)

A transmitting antenna that radiates equally in all directions (i.e., spherically) is used as a basic reference radiator in propagation work. However, in the broadcast industry, it is the usual practice to use a dipole, which has a gain of 2.15 dB relative to the isotropic (spherical) radiator, as the reference antenna.

2) Free-space loss

The basic signal strength loss, as a function of distance is:

$$Lbf = 20 \log (4 \pi d/\lambda) \text{ dB}$$

In which:

Lbf = the free-space basic transmission loss in dB
d = the distance
λ = The wavelength. Distance and wavelength are expressed in the same units.

Lbf is simply the effect of the radiated energy spreading out over a spherical region of radius "d". Stated in terms of frequency instead of wavelength, Lbf becomes:

Lbf = 32.5 + 20 log Fmhz + 20 log Dkm

Where: Fmhz is the frequency in megahertz
Dkm is the distance in kilometers

For example, at a distance of 10 km and a frequency of 100 MHz, the free-space path loss between two isotropic antennas is:

Lbf = 32.5 + 20 log (100) + 20 log (10)
= 32.5 + 20.*2.0 + 20.*1.0
= 32.5 + 40.0 + 20.0
= 92.4 dB

However, broadcast- and mobile radio engineering practice is to refer the gains of antennas to a reference dipole, which has a gain of 2.15 dB relative to an isotropic antenna. Therefore, the effective free-space loss between dipole antennas is a total of 2*2.15 dB less than between two isotropic antennas:

Lbf (dipole) = 28.2 + 20 log Fmhz + 20 log Dkm

3. The Nature of the terrain along the transmission path.

The above formula is based on the assumption that nothing intervenes into the direct path between the two end points, and, for that matter, that there is nothing even near the transmission path. Additional losses occur if terrain intervenes into, or near enough to, the path. Also, regions along the path may cause a portion of the transmitted energy to be reflected toward the receiver in such a manner as to either enhance or to decrease the received signal strength.

Therefore, a competent propagation prediction model must give detailed consideration to the terrain along the propagation path. Further, the model must examine the terrain profile and make a decision as to what computational method is most applicable to the situation at hand.

In general terms, the effects of terrain upon path loss are often less than the basic distance separation (free-space) loss. Even at one kilometer, for example, the free-space loss between

unity-gain dipole antennas is 72.5 dB at 100 MHz. Typical terrain effects range from an enhancement of a few dB (perhaps 6 to 10 dB) and, in the case of severe, multiple obstructions, some several tens of dB.

4) Effects of surface clutter (vegetation and buildings)

The effects of surface clutter (vegetation and buildings, principally) can be quite severe, as has been quantified by Okumura (1968) and Longley (1978). Both of those researchers report that excess path losses in the upper-UHF range can be in excess of 28 dB in heavily urbanized or vegetated areas.

During the course of collecting and analyzing an extensive set of signal strength measurement data on behalf of the Association of Maximum Service Telecasters ("AMST") during the late 1950's, Howard Head made certain incisive observations regarding the behavior of UHF waves in and near dense vegetation. A copy of a report, detailing Head's findings, is included herewith as Exhibit C.

Basically, Head noted that, upon entering a grove of trees from the non-shadowed side, the observed signal strength showed a rapid, exponential decrease as a function of penetration distance. As the depth of penetration into the vegetation increased, the signal strength asymptotically approached a minimum value (described by Head as being on the order of 30 dB below the field strength immediately outside the woods on the non-shadowed side). Then, when the vegetated area was exited (on the shadowed side), the recovery of signal strength was much more gradual than was the loss of strength observed upon entry into the woods. Finally, he noted that the signal strength versus distance the shadowed side very closely approximated by the of a knife-edge obstruction.

The important thrust of Head's paper is that, when one end of a terrestrial radio propagation path is immersed in surface clutter, there exists an excess path loss that is the direct effect of the clutter. This excess path loss occurs within a very short penetration distance into the clutter. Upon exit from the clutter (on the "shadowed" side), the recovery of signal strength matches the classic knife-edge diffraction case very closely.

5) Variability of signal Strength with Location and Time

Received signal strengths vary both as a function of small changes of location, on the order of a wavelength or less ("fast fading" or "Raleigh fading")and from path to similar path even though distance, terrain, and all other identifiable path characteristics are the same ("Location variability"); and time, either over a period of days to years ("long term time

variability") or more rapidly, as may be caused by passing vehicles, vegetation moving in the wind, and so on.

The small-area ("Raleigh") fading can cause signal strength variations in excess of 40 dB over a span of just a few wavelengths. An example is attached as Figure 1. The data shown graphically as Figure 1, was gathered at 880 MHz on Haines Point, near Washington, DC. The source of the signal was a Cellular telephone base site near National Airport. The path between source and measurement area was mostly over water (the Potomac River) and was uncluttered except for a thin veil of trees. The sampling rate was very fast, so as to collect 30,000 samples within a distance of about 300 feet. The horizontal lines represent the median observed signal strength over that portion of the data.

Note that signal strength minima reach to more than 30 dB below the local median values, and the maximum approach 10 dB above the median values.

If the observation point were to be held fixed, one would find that very similar variations in received signal strength occur over a period of time. It is not possible to predict, however, the length of time that observations would have to be made in order to illustrate the point. On windy days with heavy automobile traffic, the observation time period might be seconds to minutes; on quite days, it might take an hour or more. Stated in simple terms, small-area location variability maps over to the time domain.

Larger-area location variability, as has been stated, is a term used to describe the difference in path attenuation amongst otherwise identical paths. Location variability is often described as having a lognormal distribution. That is to say, that since signal strengths are generally expressed in terms of decibels relative to some stated reference value (e.g., dB relative to a microVolt per meter field strength, or dBuV), their distribution conforms to a normal (or "bell-shaped") graph.

Location variability generally increases with increasing roughness of the terrain along the propagation path and with frequency. The extent of location variability is often expressed in terms of sigma, which is the root of the sum-square variations about the mean of a set of values. If the distribution is lognormal, the usual assumption, then 68.3% of the samples are within 1.0 standard deviations ("SD") of the mean, 95.55 within 2.0 SD, and 99.7% within 3.0 SD. Typical values of sigma are 8.0 or so dB at VHF frequencies and 12.0 dB or so at UHF for gently rolling terrain.

With respect to variations in the time domain, they occur over both short time periods (seconds to minutes or hours) and over longer periods, of days to years. Depending on many

factors, including frequency, atmospheric conditions, solar activity and myriad other parameters, time variability can range from negligible to many tens of decibels.

6) Other factors ("Prediction disparity")

Despite all efforts directed towards addressing all identifiable causes of variations in received signal strength, it seems to be an immutable law of nature that the predictions will not be in exact agreement with observed values. Indeed, some of the unknown factors are immutable. For example, tree leaves will flutter in the wind; the effects of this very subtle characteristic of the radio propagation path are readily observable, and can amount to variations of received signal strength of 10 dB or more. However, there is no predicting when or where a tree leaf is going to flutter; one must simply accept that there are limits to the precision with which signal predictions can be made.

Thus, after considering all identifiable reasons for differences between actual (observed) signal strengths and the corresponding predicted values, those differences are not going to vanish. Therefore, the final consideration that must be given in a propagation model is that of the nature of the disparity between prediction and reality.

The term "prediction disparity" is used, rather than "prediction error", to emphasize that these differences are not necessarily due to an actual error in the prediction. They may, for example, be the result of the difficulty of measuring the signal strength, given the rapidity with which variations in signal strength may occur. As another example, there is generally no way of knowing how the time-variability factor has affected a given signal strength observation.

Honesty Requires Model Testing

Regardless of the apparent scientific validity of a given radiowave propagation prediction model, basic intellectual honest demands that the performance of the model be verified against actual measurement (or "ground truth") data. Therefore, it becomes necessary to describe an appropriate test-data gathering methodology before proceeding to a discussion of the development and characteristics of any such model, including those developed by myself.

Test-Data Collection Methodology

As has been noted, the received signal strength can vary over a range in excess of 40 dB over a distance range of as little as 10 to 20 wavelengths. Based on suggestions published by CCIR Volume 5, it recommended that 100 to 200 samples of signal strength be taken while the receiving antenna is being moved over a distance of 10 to 20 wavelengths. Lesser distances

or fewer samples might not be representative of the extent of variability of the signal, and observations over greater distances become contaminated with location variability.

The 50 (the median), 10, and 90 percentile values should be determined for each such "set" of 100 to 200 samples. (Practical considerations dictate that a prediction model must focus on the median value of expected signal strength, though there is a great deal to be gained through a study of the details of the variability about the median values.)

The following is a discussion of the performance of three models (the FCC's "Carey Curves", an area-prediction method used in land-mobile services, such as Cellular Radio Telephony), the Longley-Rice Model, and the Longley-Rice model corrected for the effects of vegetation and building clutter ("morphology").

The data set used in the following comparison was gathered during the summer of 1990 in Saint Tammany Parish, Louisiana. The signaling channels, which operate in the 880 MHz range, of two Cellular stations ("Slidell" and "Houltonville") were used as signal sources. St. Tammany Parish includes a wide range of electromagnetic wave propagation environments, including dense vegetation (for example, pine forests with trees exceeding one hundred feet in height, swamps with and without vegetation cover, open water (Lake Pontchartrain), farm land, and some cities of significant size. This very large collection of data included over 2,300 measurement sets, each of which consisted of 100 samples.

Comparison of Performance of Models in St. Tammany Parish

The performance of two different models, the FCC's "Carey Method and the Longley-Rice method, with and without corrections for the effects of vegetation and urbanization clutter ("morphology") has been compared, using the large collection of signal strength data, discussed above.

Performance of FCC Carey Method

With respect to the "Carey Method", described in Part 22 of the FCC Rules, it is noted that no field strength values are predicted by that method for distances of less than five miles. Therefore, points at distances of less than 5.0 miles were excluded from this study. It should also be noted that the FCC directs that the average elevation of the terrain in the distance range of two to ten miles (3 to 16 km) be used in determining effective antenna height(s), even though the locations were often at distances of less than ten miles. (As a practical matter, this point is of no concern in St. Tammany Parish, which is essentially flat and at sea level.)

The numerical results of this analysis are tabulated, below:

Site	Carey Average Disparity (dB)	Sigma dB
Houltonville	7.4	14.3
Slidell	0.2	10.7
Overall (Both Sites)	3.5	13.0

"Sigma", above, is the standard mathematical test of variability of the data about the median.

It was found that the Carey method tends to overestimate signal strength in heavily vegetated areas (such as "Evergreen Forest Land"), and to underestimate signal strength in clear areas (such as "Lakes"). Also, the Carey method overestimates more at closer distances, in general, than at greater distances.

The difference in the Carey model's performance for the Houltonville site as compared with the Slidell site probably has to do with the fact that the antennas at the former site are much lower than is the case at Slidell. The antenna radiation center is high enough at Slidell that measurements could be made at greater distances than for Houltonville, with the result that there is significantly greater diversity in the land-use and vegetation characteristics.

Clearly, the performance of the Carey model in the St. Tammany Parish environment is better than might be expected. Indeed, further examination of prediction disparity (or error) as a function of land-use leads to the question of whether this model's performance might be significantly improved if morphology effects were taken into account.

Performance of Longley-Rice Model without Morphology Adjustment

The performance of the public domain Longley-Rice model, with respect to the entire collection of some 2,300 measurement sets, encompassing 230,000 discreet samples, is summarized in the following table:

Measurement Data Vs.
Public-Domain Longley-Rice Predictions
Without Morphology Correction

Site	Average Disparity (dB)	Sigma (dB)
Houltonville	27.2	29.0
Slidell	16.2	17.1
Both Sites	21.7	23.5

The enormous disparity between the predictions of the Longley-Rice model, without morphology correction, and observed data is due to the effects of vegetation and buildings. The variability (sigma) of the disparities is also enormous, and is related to the fact that some propagation paths in St. Tammany Parish aver very difficult (e.g., heavily vegetated) and others, such as paths over Lake Pontchartrain to the (elevated) causeway, are totally clear of obstructions.

Performance of Longley-Rice Model with Morphology Adjustment

An effort has been made to adjust the predictions of the public domain Longley-Rice model (that is, version 1.2.2) to account for observed effects of morphology (vegetation, buildings, and so on). The performance of the latter model, using the same collection of measurement data, is tabulated, below:

Measurement Data Vs.
Public-Domain Longley-Rice Predictions
With Morphology Correction

Site	Average Disparity (dB)	Sigma (dB)
Houltonville	1.0	5.8
Slidell	-0.4	7.6
Both Sites	0.2	6.9

The Slidell antennas were side-mounted on a tower of several feet in cross-section. Further, that particular structure is located just a few feet from a structure of similar height and cross-section. It can be assumed that the ostensibly omni-directional radiation patterns of the Slidell antennas were significantly perturbed by the mounting arrangement. The Houltonville antennas were top-mounted and separated from each other by several feet. However, in both cases (and particularly in the Slidell instance), the antenna radiation patterns were without doubt being affected by their environments. Therefore, it is probable that the perturbing effects of the antenna mounting arrangement caused the somewhat larger sigma for the Slidell site.

Overview of Prediction Model Comparison

By was of summary of the above comparisons, it is noted that the FCC's ("Carey") contour-prediction method performed surprisingly well. That is particularly interesting in view of the fact that the Carey model, an area-prediction model, was used to make point-to-point predictions. Further, it appears that the Carey model's performance could be improved by simply taking the nature of the land-use/cover (morphology) into account.

By far the worst performer of the three models, Longley-Rice without morphology correction, does have merit. It considers the detailed effects of the terrain, for example. However, that model is severely flawed in that it does not consider the effects of vegetation and building clutter (morphology). In many cases, that deficiency can cause prediction errors of a greater magnitude that those of much simpler models, including the FCC's Carey and FM/TV prediction models.

A Caution Regarding Modeling in General

One should not assume that the performance of the Longley-Rice model could be vastly improved, once and for all, for all frequency ranges, and for all environments, simply by adding some "tweaking" factors based on this one data set. First, it should be noted that the morphology factors for the St. Tammany were specific to that case, if for no other reason than the fact that that was the only large collection of high-quality data available at that time. It should also be noted that terrain effects were virtually absent. Indeed, the major "terrain" feature in the entire area is probably the elevated causeway that crosses Lake Pontchartrain.

There is also something to be learned in regard to the rather surprising performance of the Carey model, which some might view as being a dinosaur of the radiowave propagation prediction world. Models of this genre (e.g., the FCC's broadcast FM and TV models) are, in general, a combination of physical theory and empiricism. For example, such models never predict signal strength in excess of the free-space value. They are empirical in that the have been conformed, to some extent, to measurement data. They are very simple to use; most are based only on frequency band, effective radiated power, height of transmitting antenna, and distance. By way of summary, the FCC's broadcast FM and TV models have their merits and their legitimate uses.

Exhibit B

Description of Tektronix Model VM700T NTSC Video Measurements Set

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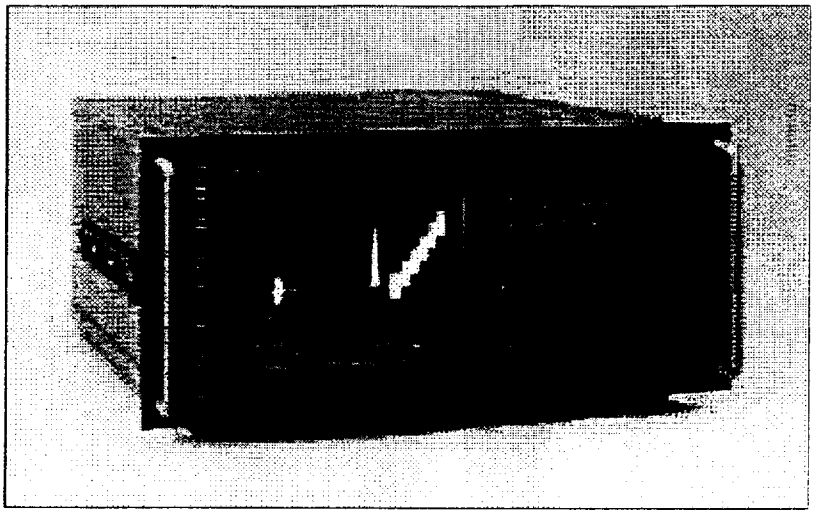
Measurement

Bookmarkable location

VM700T (turbo) Option 01 | Characteristics | Ordering Information

NTSC Video Measurements

VM700T (turbo) Option 01



VM700T

Features

- Many Capabilities in One Instrument
  - Digital Waveform Monitor
  - Digital Vectorscope
  - Picture Display
  - Group Delay and Frequency Response
  - Noise Measurement Set
  - Automatic Measurement Set
- Auto Mode
  - Unattended Monitoring of NTSC Video Signals From Studios, STLs, Earth Stations, and Transmitters
  - User-specified Limits
- Measure Mode Provides Graphic Display of Measurements
  - ICPM
  - K factor
  - Differential Gain and Phase
  - Chrominance to Luminance Delay

- o Noise Spectrum
- o Group Delay with Sin x/x
- o Color Bars
- o Relative to Reference on Most Measurements
- o Configurable for All Standard Test Signals

- Award-winning User Interface
- State-of-the-art Architecture
- Extremely Fast Update Rate
- Parallel and Serial Printer Ports
- Three Input Channels
- Channel Difference Modes
- External VGA Display Port
- Fully Documented Remote Control Operation
- Hardcopy for Analysis and Documentation

NTSC Video Measurements

Recognized with eight technical Emmy awards and one Oscar for outstanding contributions to the television industry, Tektronix world class core competencies have enabled it to design and deliver the most comprehensive solutions in the industry.

The VM700T is a product of this core competency. Recognized as the de facto industry standard that keeps pace with evolving customer needs, the VM700T is a total solution for your baseband video and audio1 monitoring and measurement needs. Features such as an extremely fast and fully automatic measurement mode as well as full manual operation provides the first time user as well as the seasoned professional an unequaled value for their test and measurement investment.

AUTOMATIC VIDEO MEASUREMENT SET
The VM700T Auto mode makes standard video transmitter measurements quickly and automatically, including those specified in RS-250C/EIA-250C, NTC-7 and RS170A. Both vertical interval and full field measurements can be made and compared with user-defined limits. A dual limit verification system is employed to generate a caution or alarm message when either limit is violated. Reports can be generated and printed automatically at operator scheduled times or triggered from a conditional event.

GRAPHIC DISPLAYS OF MEASUREMENTS
Measure mode provides virtual real-time graphic displays of measurement results automatically. Vertical interval or full field measurements including noise spectrum, group delay, K-factor, differential gain and differential phase are presented as clever, easy to understand interactive digital displays. Such displays are indispensable when extremely fast measurement update rates (up to 30 times a second) are required to provide instant feedback of critical adjustments and analysis of signal variations. User-definable limits are visually integrated into each graphic display and can be used to trigger a measurement report or a user-definable macro function. Such a function can, for example, dial out through a modem to report measurement results or control a signal router. A relative to reference mode allows normalizing to a signal source or eliminate signal path errors from the desired measurement. Up to 2 video references can be stored in NVRAM. Additionally, after downloading to a PC through the VM700T FTP driver, the video reference can be uploaded to another VM700T for reuse. A running averaging mode can be used to reduce the effect of noise. When additional measurement data is required, a user can custom configure measurement parameters and

report format.

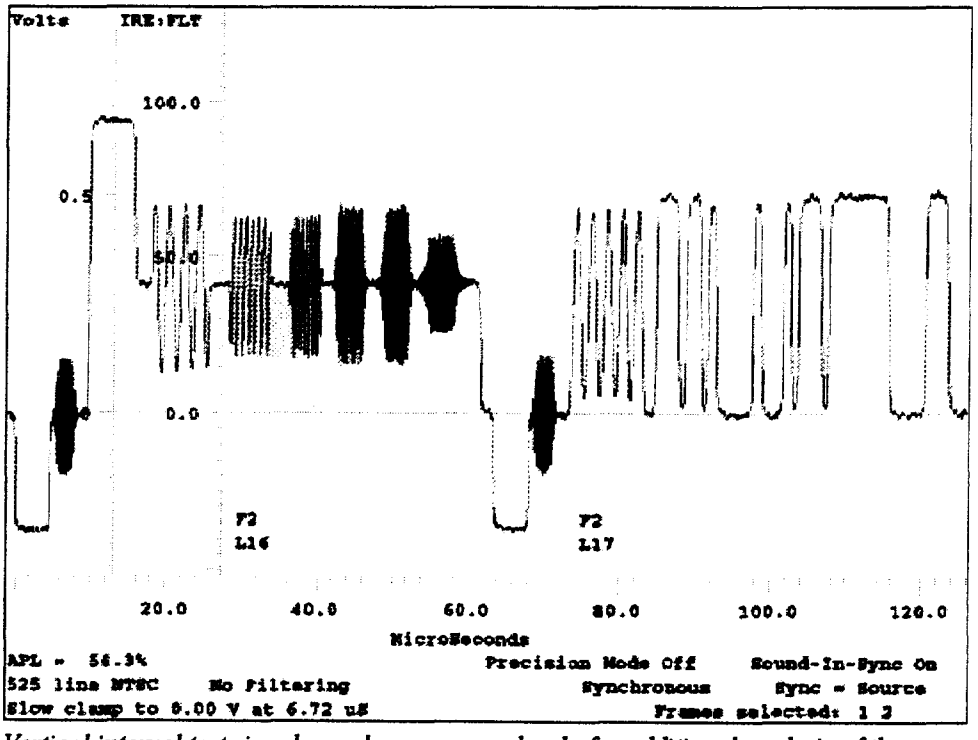
A powerful Test Signal search capability quickly and automatically locates and identifies valid test signals required for a selected measurement, eliminating the annoying and time consuming task of manually locating test signals.

DIGITAL WAVEFORM MONITOR/VECTORSCOPE

The VM700T Waveform mode application provides real time graphics displays of the video signal allowing many additional measurements to be made manually. Easy to use measurement cursors are available to measure time, frequency and amplitude parameters of a video signal. These cursors allow a very quick and precise location of the 10%, 50% and 90% points on any transition. Cursor mode also employs an automatic calculation in the wave shape in the center of the display. The parameters calculated are sine peak-to-peak amplitude, frequency, and offset from blanking level. This is very useful for frequency response measurements with the Multiburst signal.

The waveform display can be expanded around any point both vertically and horizontally. Since the data is digitized, the display remains bright and easy to ready at all expansion factors. The scales automatically expand with the waveform, so all units are correct as displayed. A channel difference mode (A-B, A-C, B-A, B-C, C-A, and C-B) is also provided. A screen memory selection enables Envelope mode, which is useful for looking at teletext, Jitter, or other changes over time.

Vector mode provides the normal vectorscope display. The vectors may be rotated or expanded, with the rotation angle and gain values displayed numerically on the screen.



Vertical interval test signals can be seen very clearly for additional analysis of the signal. These can be printed as support documentation for automatic measurement results.

A unique "Find ColorBars" feature searches all video for ColorBars and displays the vectors if found. The vectors can be referenced to either the selected channel's burst or the burst of one of the other two channels or continuous subcarrier. The phase difference between the selected

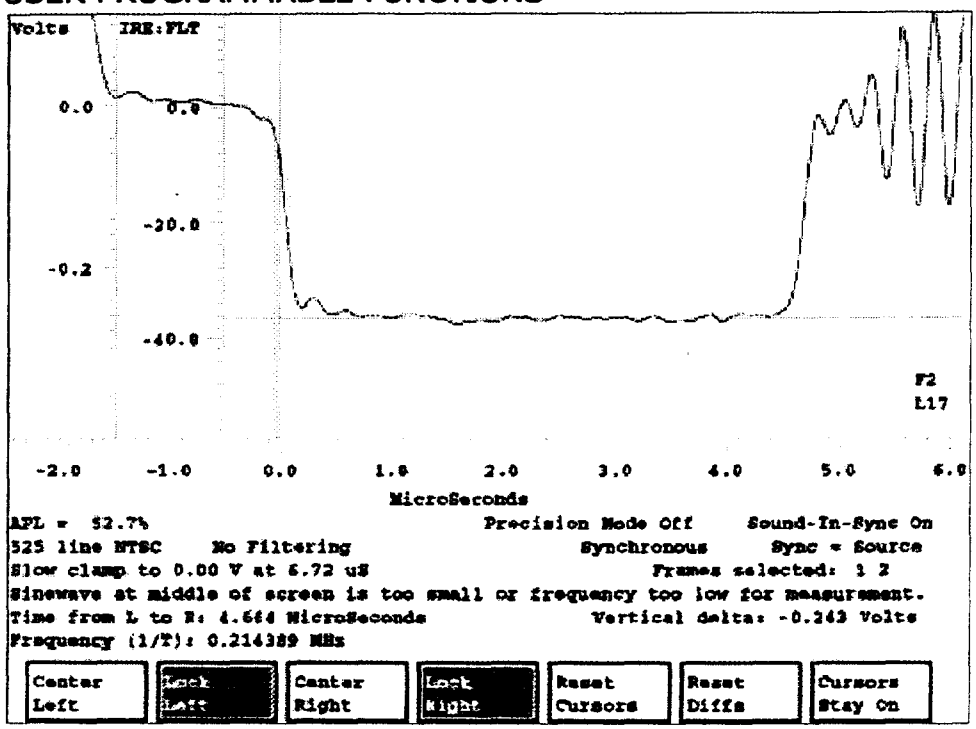
channel and the reference is always displayed.

Select Line in both Waveform and Vector modes can be used to quickly specify any line for display or automatic measurement if it is the proper signal.

PICTURE MODE

The signal source can be quickly verified using the picture display. Additionally, a "bright-up" line select mode allows a user to select any video line for use in Measure mode or for viewing in Waveform or Vector mode.

USER PROGRAMMABLE FUNCTIONS



Even a single horizontal synchronization pulse can be displayed at a high intensity.

Function mode is an extremely powerful feature that allows a user to store a sequence of user operations as a macro function for later "playback."

For example, a set of measurements (complete with hardcopy commands) to be made on a transmitter demodulator video output, could be stored as a function labeled "DEMOD." The function "playback" could then be initiated manually, remotely or completely automatically as a user specified timed event. Function files can be stored as a text file on a PC for editing, copying or uploading to another VM700T. Other function capabilities include controlling of external serial devices such as video/audio routers, switchers, signal generators, telephone modems and many other devices which support RS232 communications.

HARDCOPY

All information on the screen may be printed in high resolution graphics on printers supporting PostScript®, Hewlett-Packard® LaserJet™, DeskJet™, and ThinkJet™, or 24-Pin Epson® graphics via the Centronics compatible parallel port or standard RS-232C interface.

Automatic measurement results in text format can be printed on most ASCII printers using the parallel or serial ports.

REMOTE OPERATION

The VM700T has a powerful and fully documented remote control language. The VM700T can thus be operated from a remote terminal via RS-232C to monitor unattended transmission systems. In addition, all files can be uploaded to a main computer, and downloaded to other VM700Ts. Two different protocols are supported: FTP (File Transfer Protocol) and TELNET. The user can also select a "no protocol" mode of the RS-232C interface when dealing with low baud rates. However, file transfers can only take place with FTP.

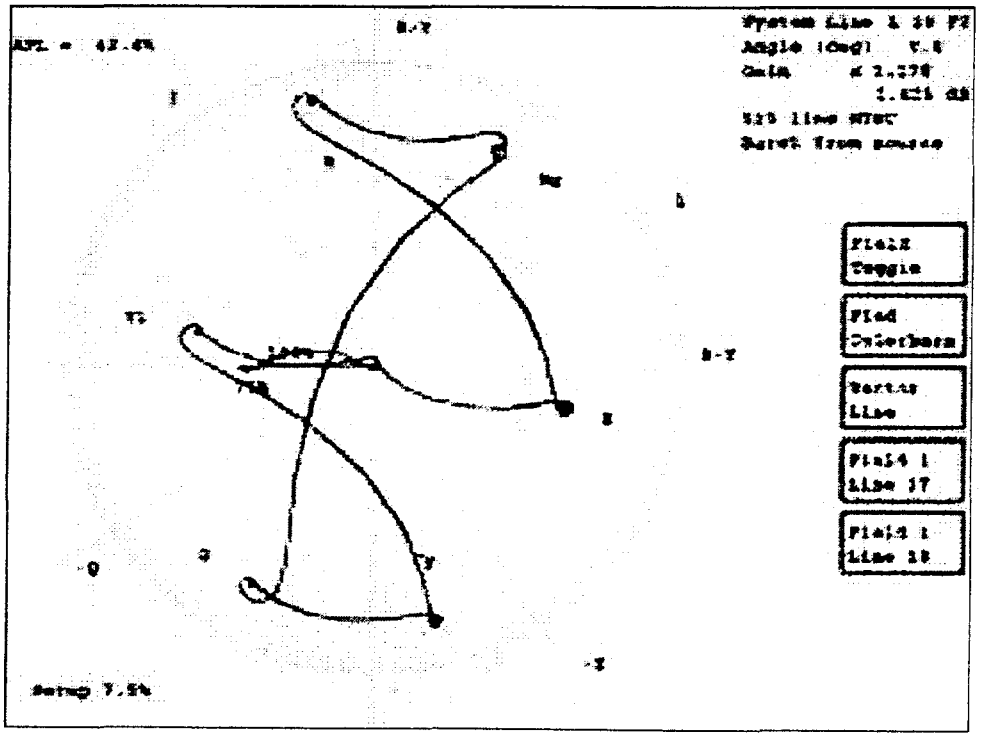
SPECIFICATIONS

The performance requirements cited in this section are valid only within the following environmental limits:

Temperature range of 0 to 50°C, with a minimum warm-up time of 20 minutes. The following tables list each measurement and its performance requirement.

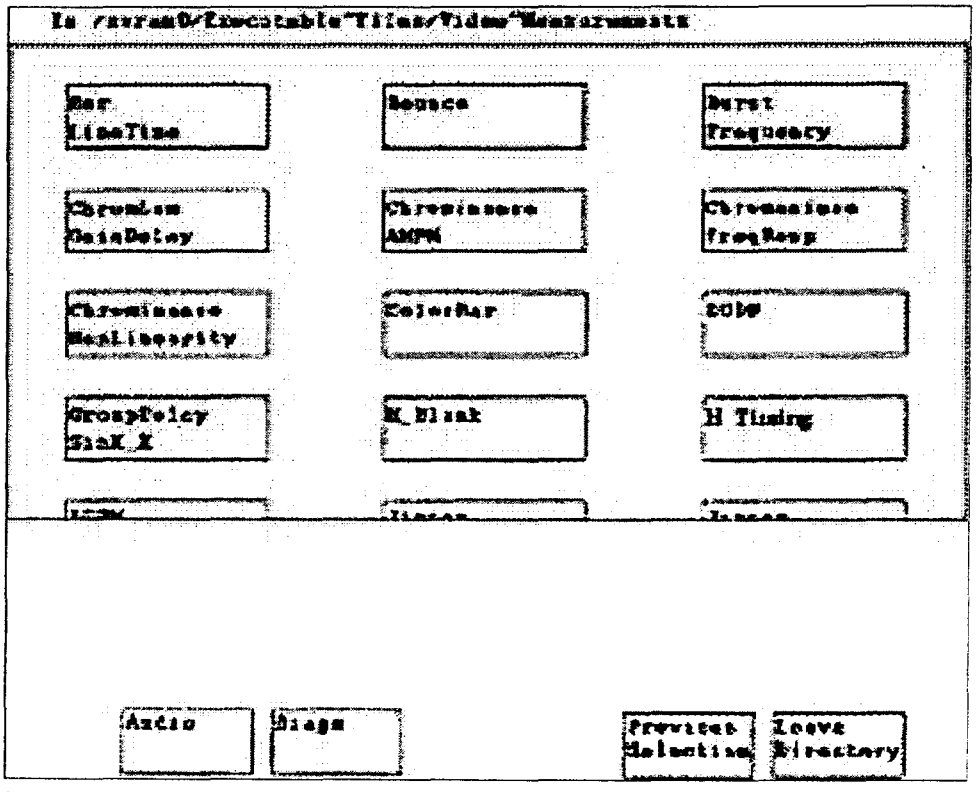
The range specifies the extremes between which a measurement can be made.

All measurement accuracies specified are valid only with nominal input signals of 1 V pk-pk (± 6 dB) with an unweighted signal-t-noise ratio of at least 60 dB on the incoming signal and a termination accuracy of ± 0.025% (Tektronix PN 011-0102-01 or equivalent).

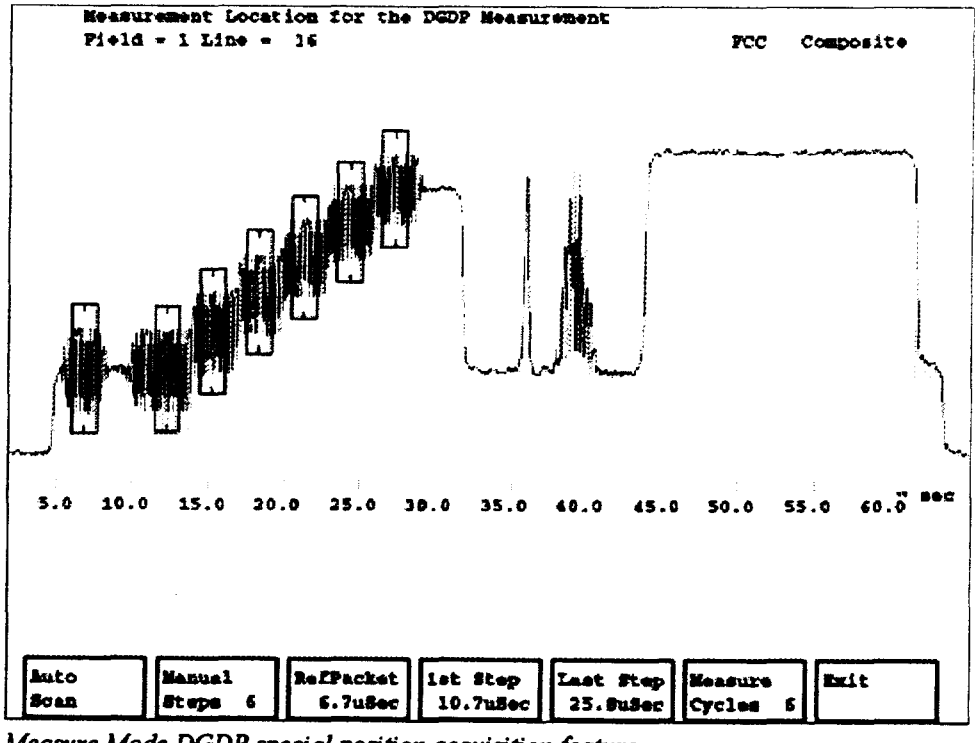


In Vector Mode, the VM700T becomes a digital vectorscope with an electronic graticule. A "ColorBar Search" feature makes it easy to quickly display a line containing a color bar test signal.

Picture Mode display. (Video courtesy of KOIN-TV, Portland, Oregon)



Main Measure Mode display of available measurements.



Measure Mode DGDP special position acquisition feature.

MEASURE MODE*[1,2]

BAR LINE TIME

Measurement	Range	Absolute Mode Accuracy	Relative Mode Accuracy
Bar Level	50 to 200 IRE	±0.5%	±0.2%
Sync Level	20 to 80 IRE	±0.5%	±0.2%
Sync to Bar Top	70 to 280 IRE	±0.5%	±0.2%
Sync/Bar Ratio	10% to 125% 100% nominal	±0.5%	±0.2%
Bar Tilt (Rec 569)	0 to 20%	±0.2%	±0.1%
Line Time Distortion (Rec 567)	0 to 20%	±0.2%	±0.1%
Bar Width	10 µS to 30 µS	±100 nS	NA

BOUNCE

Measurement	Range	Accuracy
Peak Deviation	0 to 50%	±1%
Settling Time	0 to 10 sec	±100 msec

BURST FREQUENCY*[3]

Measurement	Range	Relative Mode Accuracy
Burst Frequency Error	±100 Hz	±0.5

CHROMINANCE TO LUMINANCE GAIN AND DELAY

Measurement	Range	Absolute Mode Accuracy	Relative Mode Accuracy
Chrominance to Luminance Delay	±300 ns	±5 ns	±1.0 ns
Chrominance to Luminance Gain Ratio	0 to 160%	±1.0%	±0.1%

CHROMINANCE FREQUENCY RESPONSE

Measurement	Range	Absolute Mode Accuracy	Relative Mode Accuracy
Reference Amplitude	0 to 100 IRE	±1%	±0.5%
Frequency Response	0 to 100 IRE	±1%	±0.5%

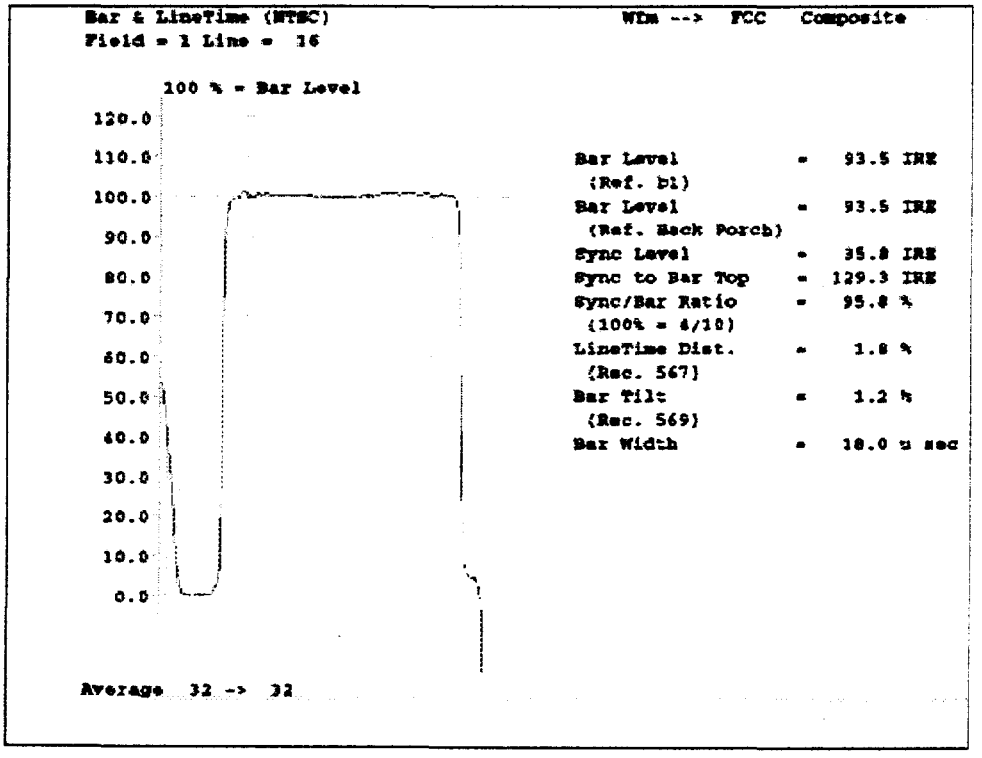
CHROMINANCE NOISE

Measurement	Range	Absolute Mode Accuracy
AM Noise	-20 to -80 dB	±1 dB (-20 to -60 dB)
PM Noise	-20 to -70 dB	±1 dB (-20 to -60 dB)

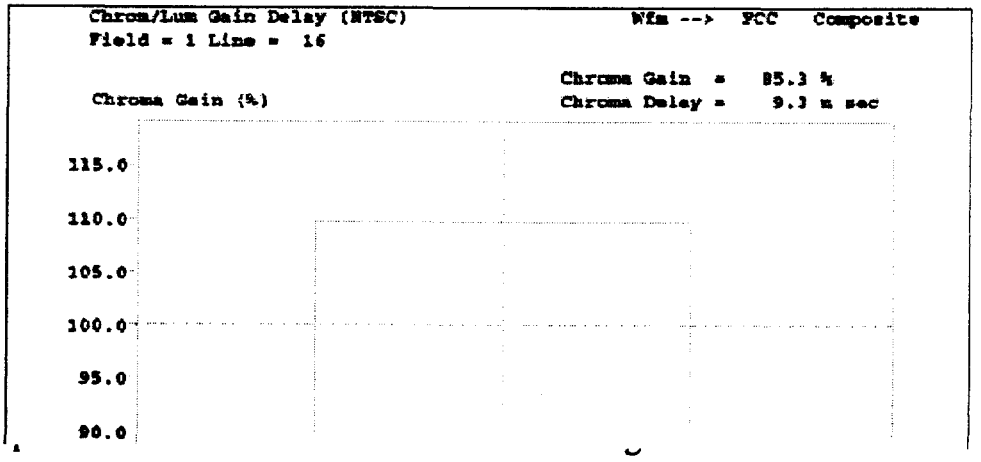
CHROMINANCE NON-LINEARITY*[4]

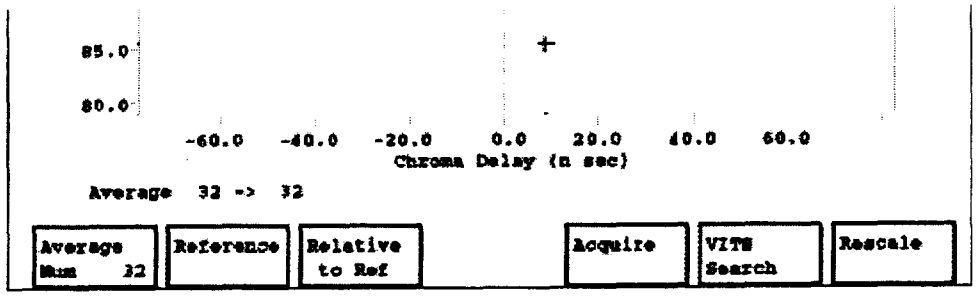
Measurement	Range	Absolute Mode Accuracy	Relative Mode Accuracy
Chrominance Amplitude	0 to 100%	±0.4%	±0.2%
Chrominance Phase	0 to 360 deg	±1 deg	±0.2 deg
Chrominance to Luminance Intermodulation	-50 to +50%	±0.2%	±0.2%

[1] All accuracies for measurements with averaging capabilities assume the default average of 32.
[2] All accuracies for measurements with relative to reference mode assume an average of 256 was used to create the reference.
[3] Requires a reference signal.
[4] Accuracies for chrominance non-linearity amplitude and phase measurements assume an average of 256.

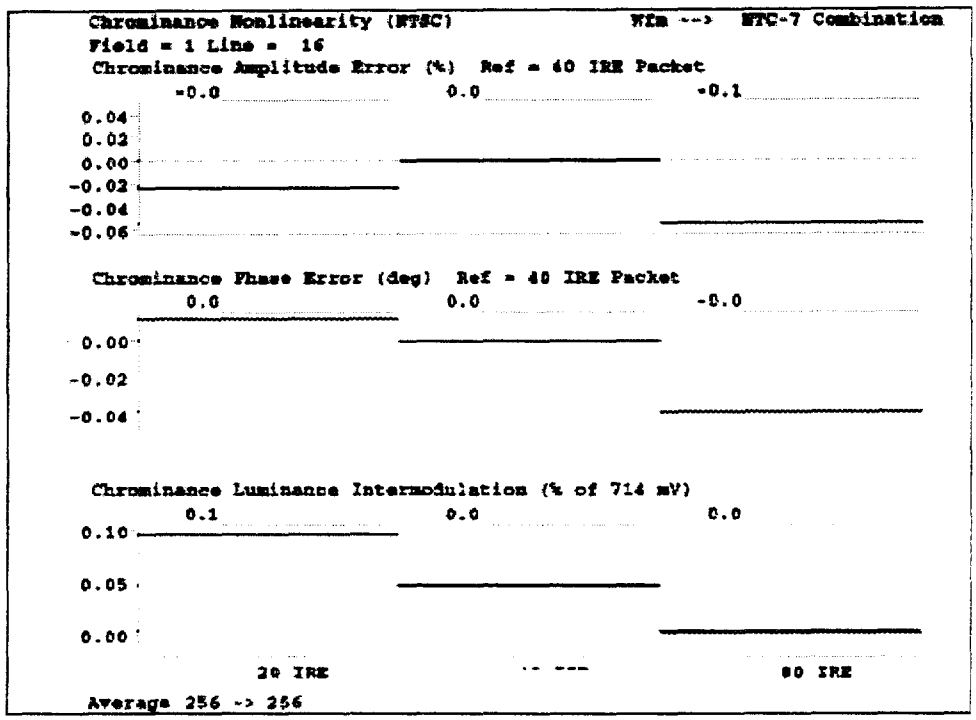


Bar Line Time measurement





Chrominance to Luminance Gain and Delay measurement.



Chrominance Non-Linearity measurement.

COLOR BAR

Measurement	Range	Absolute Mode Accuracy	Relative Mode Accuracy
Luminance Level	0 to 100 IRE (0 to 714.3 mV)	±0.5 IRE	±0.2%
Chrominance Level (excluding gray and black)	0 to 100 IRE (0 to 714.3 mV)	±1.0% of nominal	±0.2%
Chrominance Phase	±180 deg of nominal	±0.5 deg of nominal	±0.1 deg

SMPTE COLOR BARS NOMINAL VALUES

Color	LUM (mV)	Chroma P-P (mV)	Phase (degrees)
Yellow	494.6	444.2	167.1
Cyan	400.4	630.1	283.4
Green	345.9	588.5	240.8
Magenta	256.7	588.5	60.8
Red	202.2	630.1	103.4
Blue	108.1	444.2	347.1

DIFFERENTIAL GAIN AND PHASE

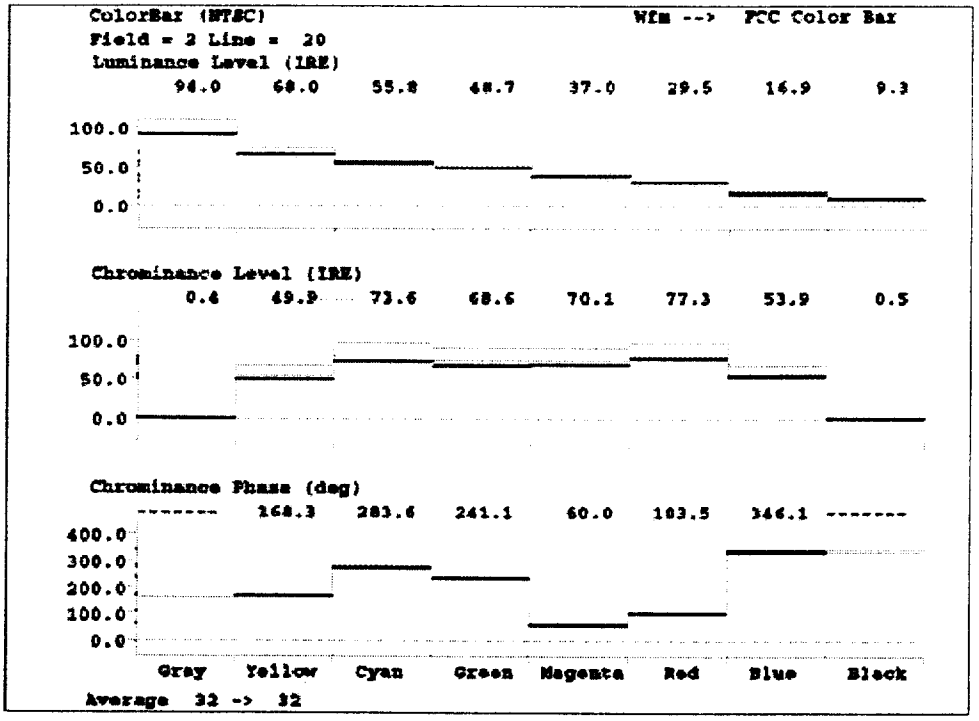
Measurement	Range	Absolute Mode Accuracy	Relative Mode Accuracy
Differential Gain	0 to 100%	±0.3%	±0.03%
Differential Phase	0 to 360 deg	±0.3 deg	±0.03 deg

FREQUENCY RESPONSE AND GROUP DELAY

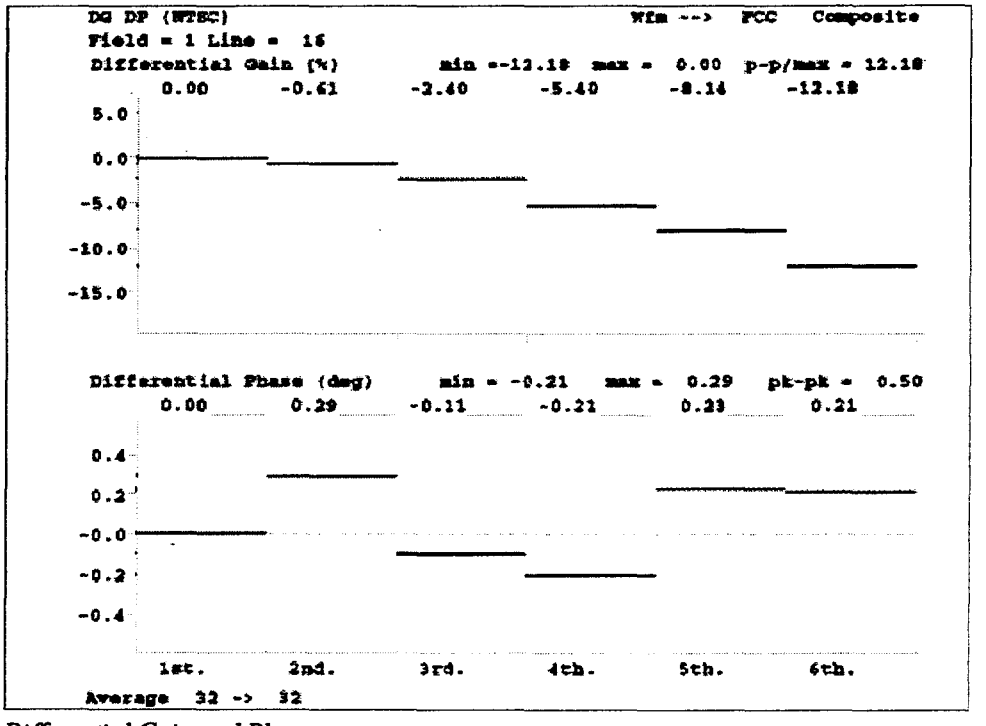
Measurement	Range	Absolute Mode Accuracy	Relative Mode Accuracy
Frequency Response	±40 dB	±1.0 dB	±0.3 dB
Group Delay	±1.0 µs	±20 ns	±5 ns

HORIZONTAL BLANKING

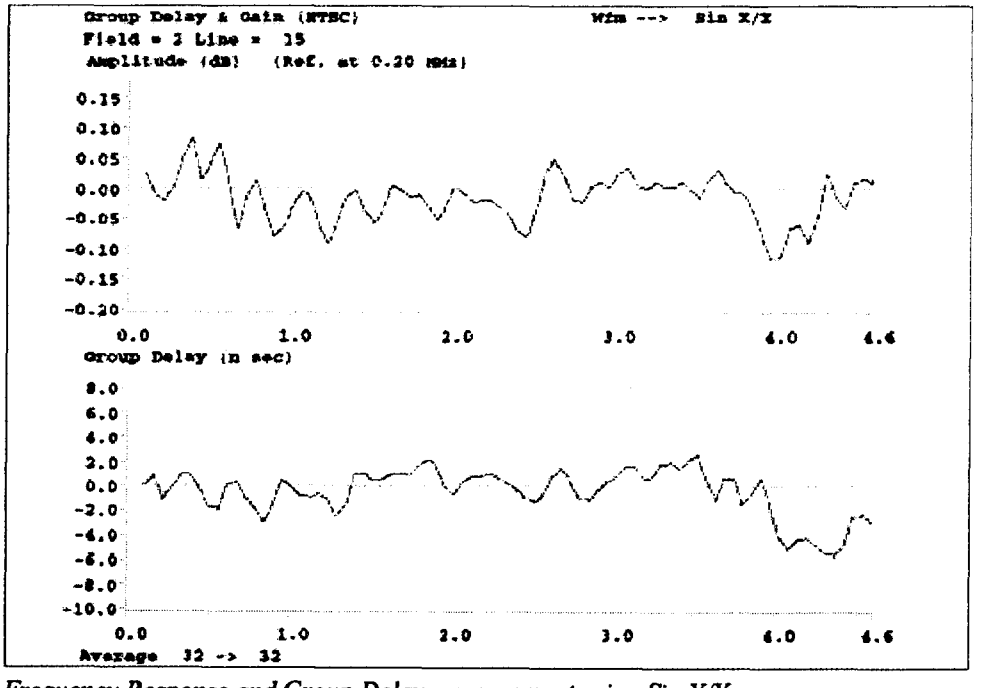
Measurement	Range	Absolute Mode Accuracy
Blanking Start	0.1 to 4.2 µs	±50 ns
Blanking End	6.8 to 12.2 µs	±50 ns
Blanking Width	6.9 to 16.4 µs	±50 ns



Color Bar measurement.



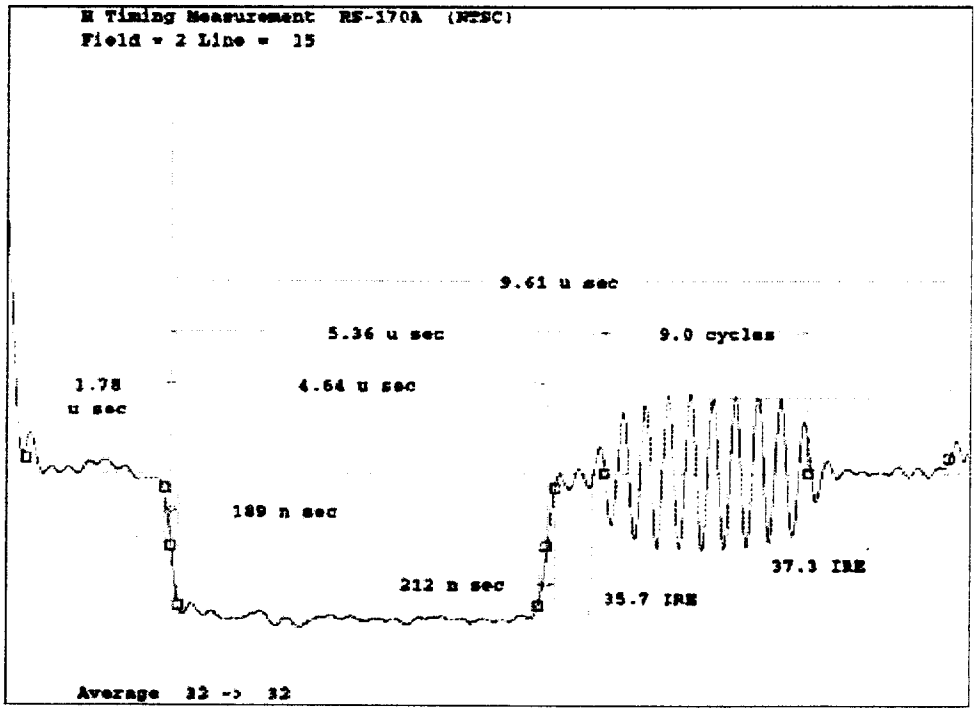
Differential Gain and Phase measurement.



Frequency Response and Group Delay measurement using Sin X/X.

HORIZONTAL TIMING

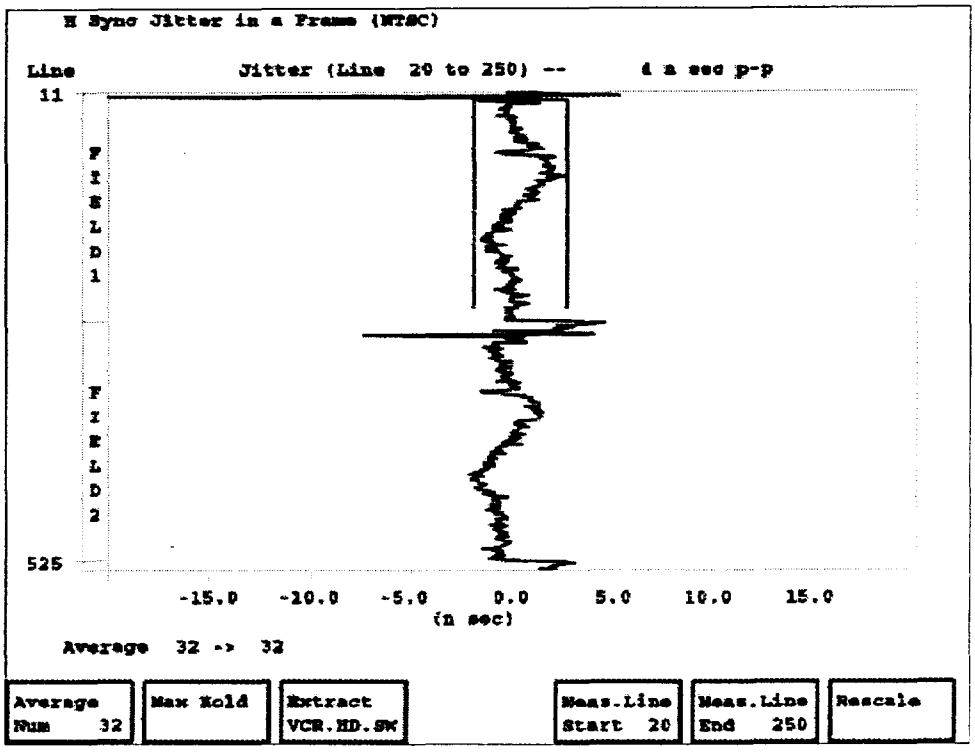
Measurement	Range	Absolute Mode Accuracy
Burst Level	10 to 80 IRE	±0.5%
Horizontal Sync Rise and Fall Time	80 ns to 1 µs	±10 ns
Horizontal Sync Width	3 to 7 µs	±10 ns
Burst Width	6 to 13 cycles	±0.1 cycles (FCC) ±0.5 cycles (RS-170A)
Sync to Burst Start (RS-170A)	4 to 10 µs	±150 ns
Sync to Burst End (FCC)	4 to 10 µs	±25 ns
Front Porch	0.1 to 3.5 µs	±10 ns (FCC) ±10 ns (RS-170A)
Sync to Setup	8.8 to 13.0 µs	±10 ns
Breezeway (FCC)	0.1 to 5 µs	±25 ns
Sync Level	20 to 80 IRE	±0.5%



Horizontal Timing measurement.

INCIDENTAL CARRIER PHASE MODULATION

Measurement	Range	Accuracy
ICPM (requires zero Carrier Pulse and the quadrature output of the demodulator on Channel C)	0 to 90 deg	± 1.0 deg



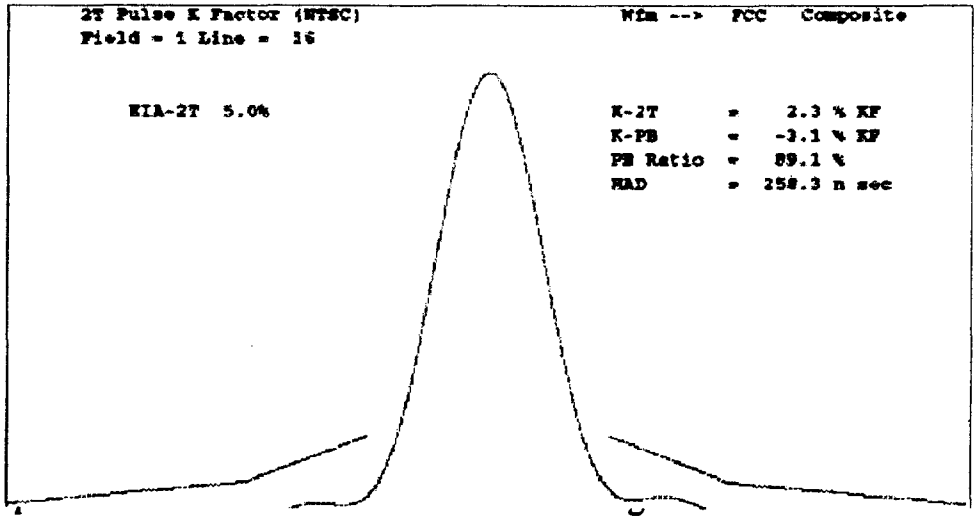
H_Jitter.

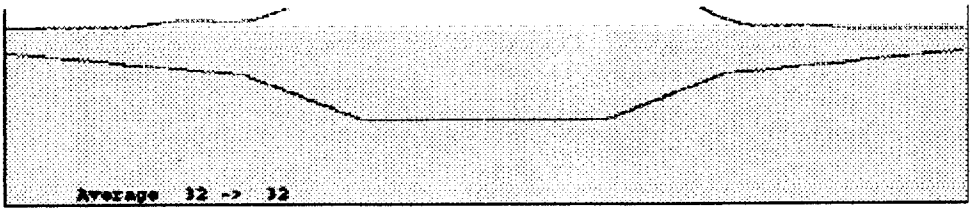
JITTER

Measurement	Range	Absolute Mode Accuracy
Jitter (2 Field)	±20 µs	±10 ns
Jitter Long Time	±20 µs	±10 ns

K-FACTOR

Measurement	Range	Absolute Mode Accuracy
2T Pulse K-Factor	0 to 10% Kf	±0.3%
KPB	10 to 5% KPB	±0.3%
Pulse to Bar Ratio	10 to 125%	±0.7%
Pulse Half Amplitude Duration (HAD)	100 to 500 ns	±5 ns

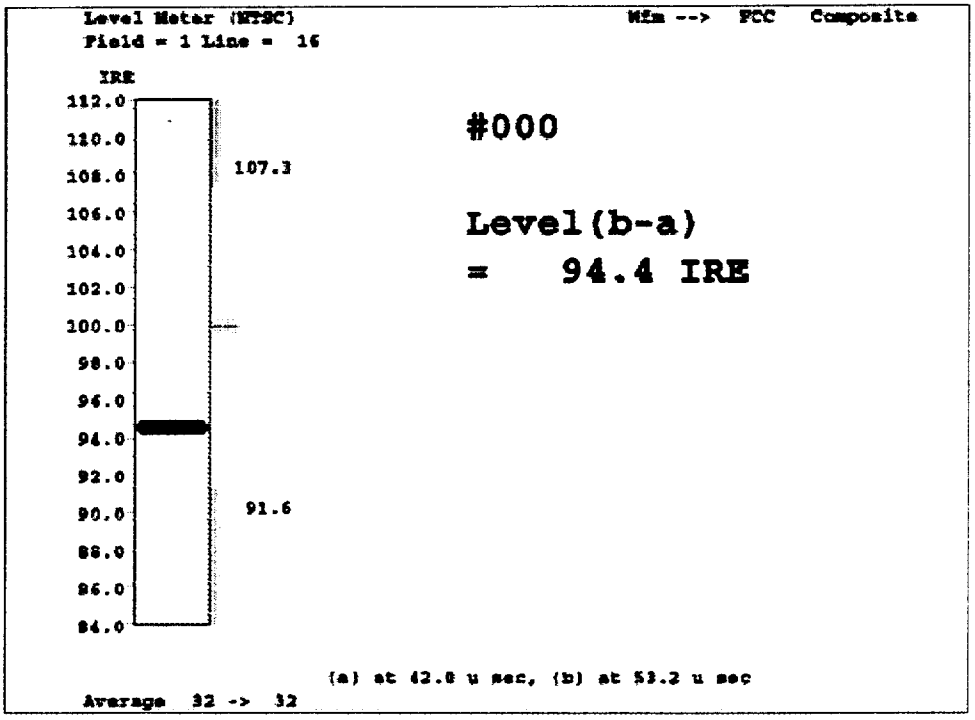




K-factor measurement.

LEVEL METER

Measurement	Range	Accuracy
Level Meter	0 to 1.4 V	±3.5 mV



Level Meter measurement

LINE FREQUENCY

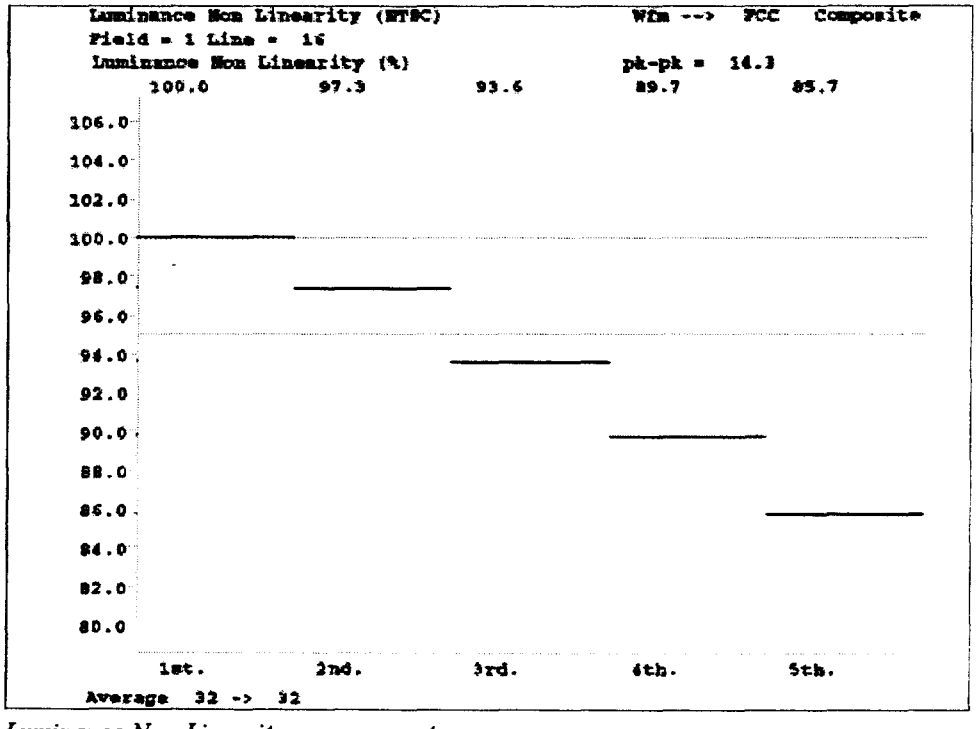
Measurement	Range	Accuracy
Line Frequency	±3%	±0.1%
Field Frequency	±3%	±0.1%

LUMINANCE NON-LINEARITY

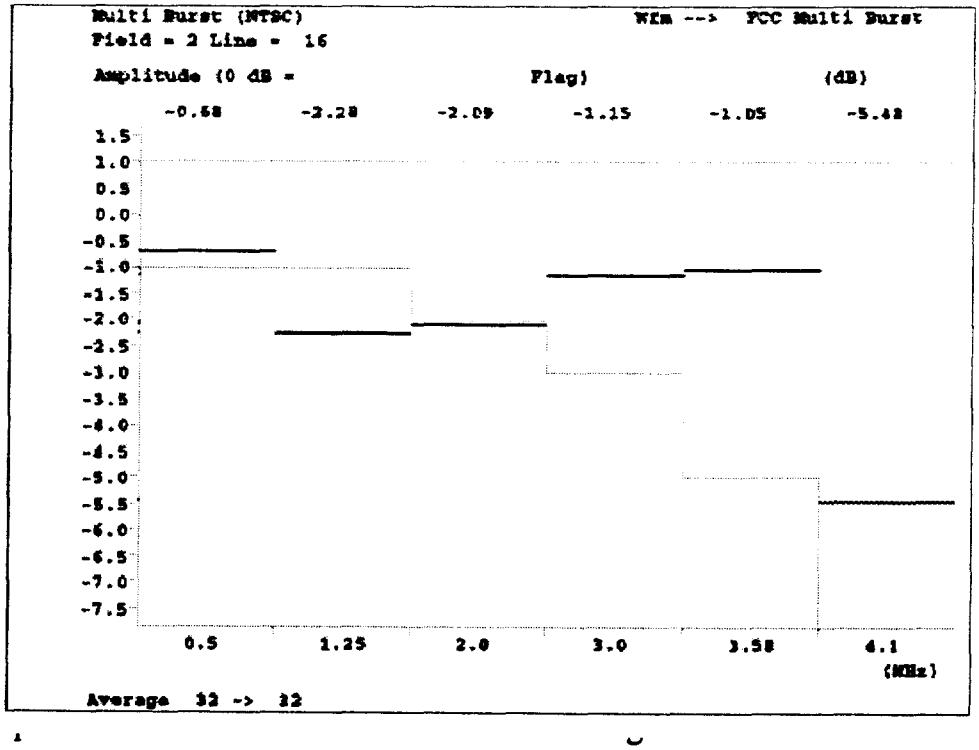
Measurement	Range	Absolute Mode Accuracy	Relative Mode Accuracy
Luminance Non-linearity	0 to 100%	±0.4%	±0.2%

MULTIBURST*5

Measurement	Range	Absolute Mode Accuracy	Relative Mode Accuracy
Reference Flag or Packet Amplitude	30 to 130 IRE	±1%	NA
Other Packets	-40 to +6 dB	±0.1 dB	±0.03 dB
*[5] *Total Harmonic Distortion on packets must be <=46 dB.*			



Luminance Non-Linearity measurement.



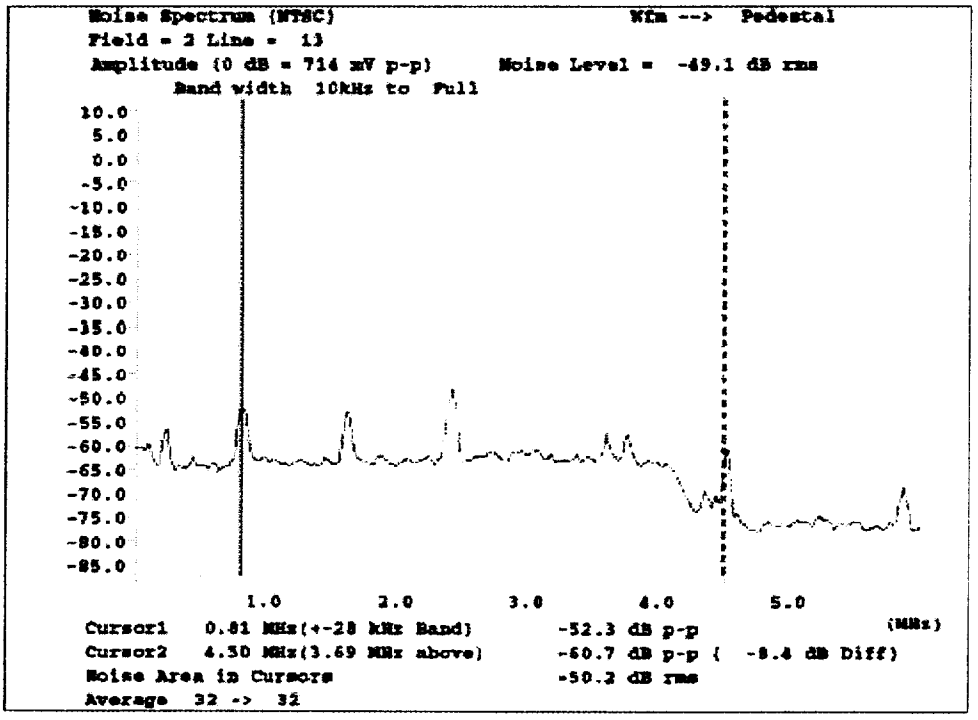
Multiburst measurement.

NOISE SPECTRUM

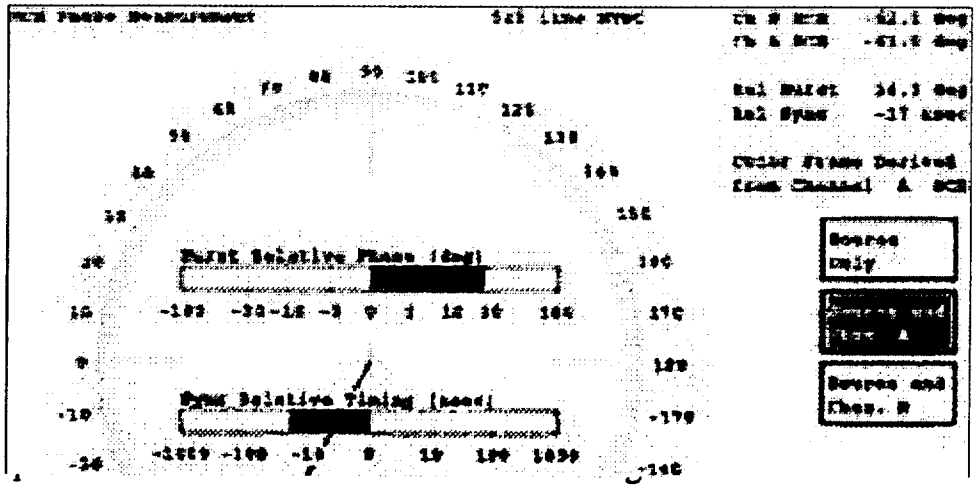
Measurement	Range	Absolute Mode Accuracy
Unweighted Signal-to-Noise Ratio (5 MHz Low Pass)	-20 to -80 dB	±0.4 dB (-20 to -60 dB) ±1.0 dB (-60 to -70 dB)
Weighted Signal-to-Noise Ratio (5 MHz Low Pass and Unified Weighting)	-20 to -80 dB	±1.0 dB (-20 to -0 dB) ±2.0 dB (-60 to -70 dB)

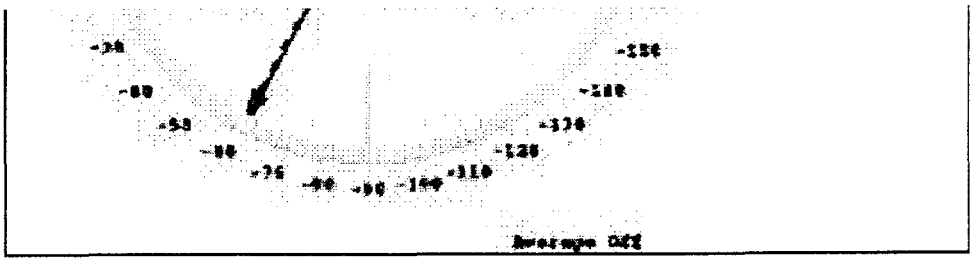
SCH PHASE

Measurement	Range	Absolute Mode Accuracy
SCH Phase	±90 deg	±5 deg
Sync Timing	±1 µS	±10 nS
Burst Timing	±180 deg	±5 deg

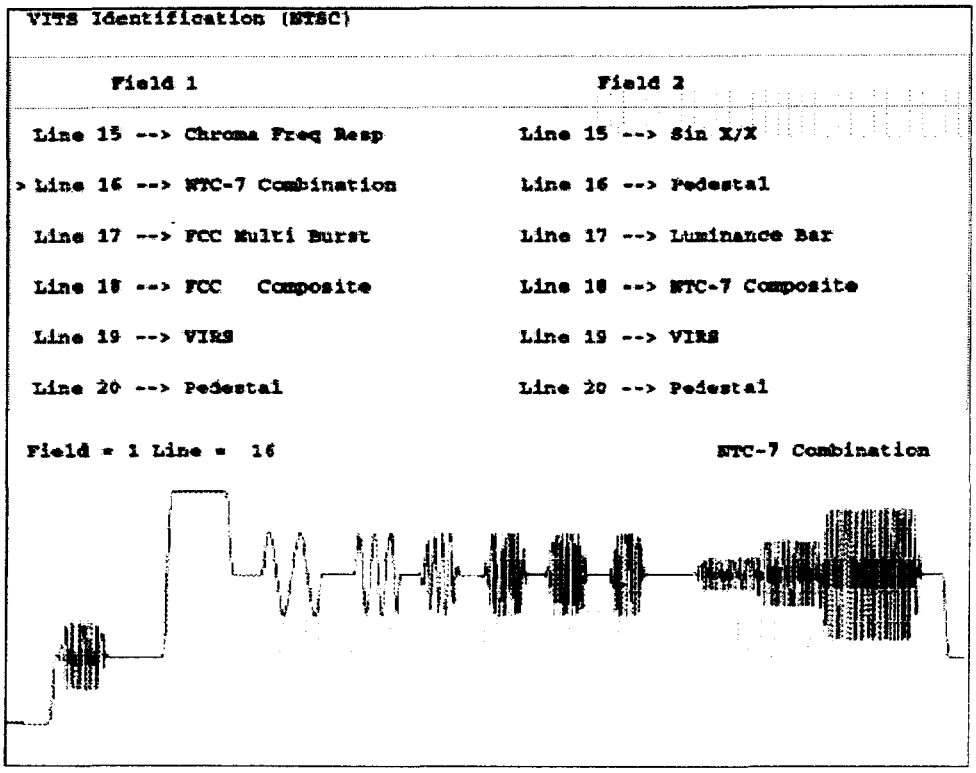


Noise Spectrum measurement.





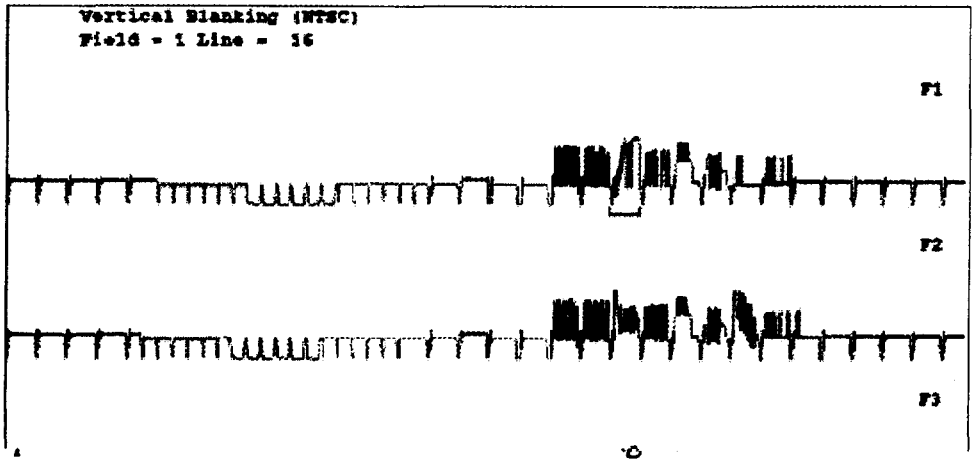
SCH Phase measurement.

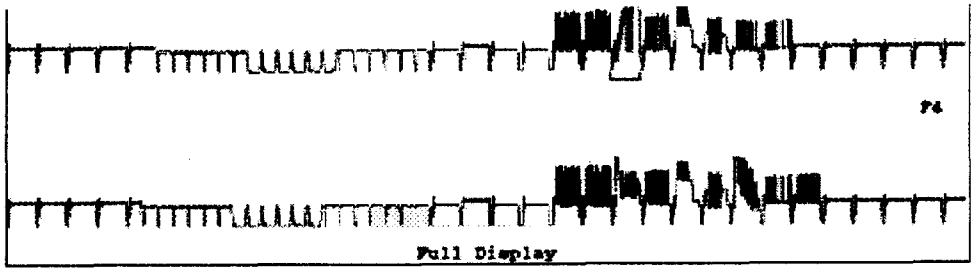


VITS ID display.

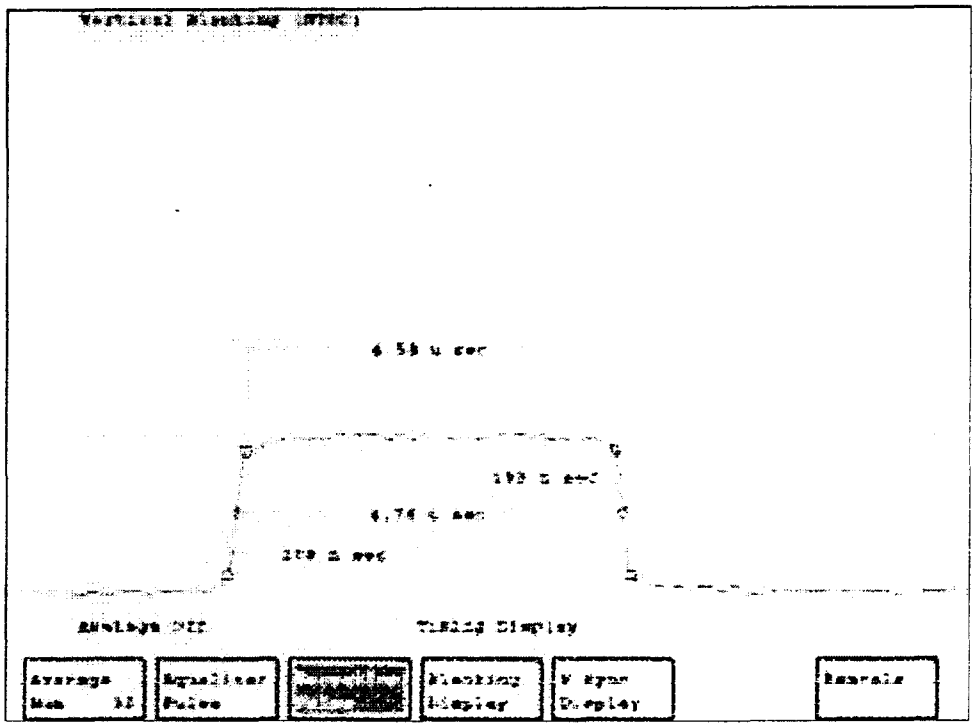
VERTICAL BLANKING

Measurement	Range	Absolute Mode Accuracy
Equalizing Pulse Width	80 ns to 1 µs	±10 ns
Serration Pulse Width	80 ns to 1 µs	±10 ns





Vertical Blanking display



Vertical Blanking Serration Pulse measurement.

Auto Mode

RS-170A HORIZONTAL BLANKING INTERVAL TIMING MEASUREMENTS

Measurement	Range	Accuracy	Test Signal
Color Burst Width	6 to 13 cycles	±0.1 cycles	Horizontal Blanking
Front Porch Duration	0.5 to 2 µs	±20 ns	Horizontal Blanking
Horizontal Blanking Width	6 to 30 µs	±50 ns	Horizontal Blanking
Horizontal Sync Rise Time and Fall Time	80 to 120 ns, 120 to 300 ns 300 ns to 1.0 µs	-10 to +30 ns, ±20 ns ±30 ns	Horizontal Blanking
Horizontal Sync Width	1 to 8 µs	±10 ns	Horizontal Blanking
SCH Phase	±90 deg	±5 deg	Horizontal Blanking
Sync to Setup	5 to 18 µs	±20 ns	Horizontal

			Blanking
Sync to Start of Burst	4 to 8 µs	±140 ns (0.5 cycles) ±20 ns	Horizontal Blanking

RS-170A VERTICAL BLANKING INTERVAL

Measurement	Range	Accuracy	Test Signal
Equalizing Pulse Width	1 to 20 µs	±10 ns	Vertical Blanking
Serration Width	1 to 20 µs	±10 ns	Vertical Blanking
Vertical Blanking Width	19 to 29 lines	-0.1 lines to +0.2 lines	Vertical Blanking

FCC HORIZONTAL BLANKING INTERVAL TIMING MEASUREMENTS

Measurement	Range	Accuracy	Test Signal
Breezeway Width	0.2 to 3.5 µs	±25 ns	Horizontal Blanking
Color Burst Width	6 to 13 cycles	±0.1 cycles	Horizontal Blanking
Front Porch Duration	0.5 to 2 µs	±10 ns	Horizontal Blanking
Horizontal Blanking Width	6 to 30 µs	±10 ns	Horizontal Blanking
Horizontal Sync Rise Time and Fall Time	80 to 120 ns 120 to 300 ns, 300 ns to 1.0 µs	-10 to +30 ns ±20 ns, ±30 ns	Horizontal Blanking
Horizontal Sync Width	1 to 8 µs	±10 ns	Horizontal Blanking
Sync to Setup	5 to 18 µs	±20 ns	Horizontal Blanking
Sync to End of Burst	6 to 15 µs	±20 ns	Horizontal Blanking

FCC VERTICAL BLANKING INTERVAL TIMING MEASUREMENTS

Measurement	Range	Accuracy	Test Signal
Equalizing Pulse Width	25 to 100%, of nominal horizontal sync pulse width	±0.3%	Vertical Blanking
Serration Width	1 to 20 µs	±10 ns	Vertical Blanking
Vertical Blanking Width	19 to 29 lines	-0.1 lines to +0.2 lines	Vertical Blanking

AMPLITUDE AND PHASE MEASUREMENTS

Measurement	Range	Accuracy	Test Signal
Average Picture Level (APL)	0 to 200%	±3.0%	Full Field
Bar Top	0 to 90% of Maximum Carrier	±0.1%	FCC/NTC-7 Composite
Bar Amplitude	0 to 200 IRE	±0.3 IRE	FCC/NTC-7 Composite
Chrominance to Luminance Delay (Relative Chroma Time)	±300 ns	±5 ns	FCC/NTC-7 Composite
Chrominance to Luminance Gain (Relative Chroma Level)	0 to 160%	±1%	FCC/NTC-7 Composite
Differential Gain	0 to 100%	±0.3%	FCC/NTC-7 Composite
Differential Phase	0 to 360 deg	±0.3 deg	FCC/NTC-7 Composite

Luminance Non-linear Distortion	0 to 50%	±0.4%	FCC/NTC-7 Composite
Relative Burst Gain	±100%	±0.3%	FCC/NTC-7 Composite
Relative Burst Phase	±180 deg	±0.3 deg	FCC/NTC-7 Composite
Burst Amplitude (% of sync)	25 to 200% of sync	±1.0%	Horizontal Blanking
Burst Amplitude (% of Bar)	10 to 80% of Bar (10 to 80 IRE when Bar is not used)	±0.4% (±0.4 IRE)	Horizontal Blanking
Sync Amplitude (% of Bar)	20 to 80% of Bar (20 to 80 IRE when Bar is not used)	±0.3% (±0.3 IRE)	Horizontal Blanking

AMPLITUDE AND PHASE MEASUREMENTS (CONTINUED)

Measurement	Range	Accuracy	Test Signal
Blanking Level	0 to 90% of Maximum Carrier	±0.2%	Horizontal Blanking
Sync Variation	0 to 50% of Maximum Carrier (0 to 50% of Bar when Zero Carrier is not used and 0 to 50 IRE when Zero Carrier and Bar are not used)	±0.3% for Zero Carrier (±0.3% for Bar and ±0.3 IRE for no Zero Carrier and no Bar)	Horizontal Blanking
Blanking Variation	0 to 50% of Maximum Carrier Maximum Carrier when Zero Carrier is not used and 0 to 50 IRE when Zero Carrier and Bar are not used)	±0.3% for Zero Carrier (±0.3% for Bar and ±0.3 IRE for no Zero Carrier and no Bar)	Horizontal Blanking

FREQUENCY RESPONSE MEASUREMENTS

Measurement	Range	Accuracy	Test Signal
Multiburst Flag Amplitude	0 to 90% of Maximum Carrier (20 to 130% of Bar when Zero Carrier is not used and 20 to 130 IRE when Zero Carrier and Bar are not used)	±0.5% for Zero Carrier (±0.5% for Bar and ±0.5 IRE for no Zero Carrier and no Bar)	FCC Multiburst or NTC-7 Combination
Multiburst Packet	0 to 100% of Flag NTC-7 Combination	±1% of Flag	FCC Multiburst or Amplitudes

INCIDENTAL CARRIER PHASE MODULATION

Measurement	Range	Accuracy	Test Signal
ICPM (requires Zero Carrier Pulse and the quadrature output of the demodulator on channel C)	0 to 30 deg	±1.0 deg	FCC or NTC-7 Composite

COLOR BAR MEASUREMENTS

Measurement	Range	Accuracy	Test Signal
Color Bar Amplitude Errors	±100% of nominal	±1.0%	FCC Color Bars
Color Bar Phase Errors	±180 deg from nominal	±0.5 deg	FCC Color Bars
Color Bar Chrominance to Luminance Gain Ratio	0 to 200% of nominal	±2%	FCC Color Bars

OUT-OF-SERVICE MEASUREMENTS

Measurement	Range	Accuracy	Test Signal
Field Time Distortion	0 to 40%	±0.5%	Field Square Wave

WAVEFORM DISTORTION MEASUREMENTS

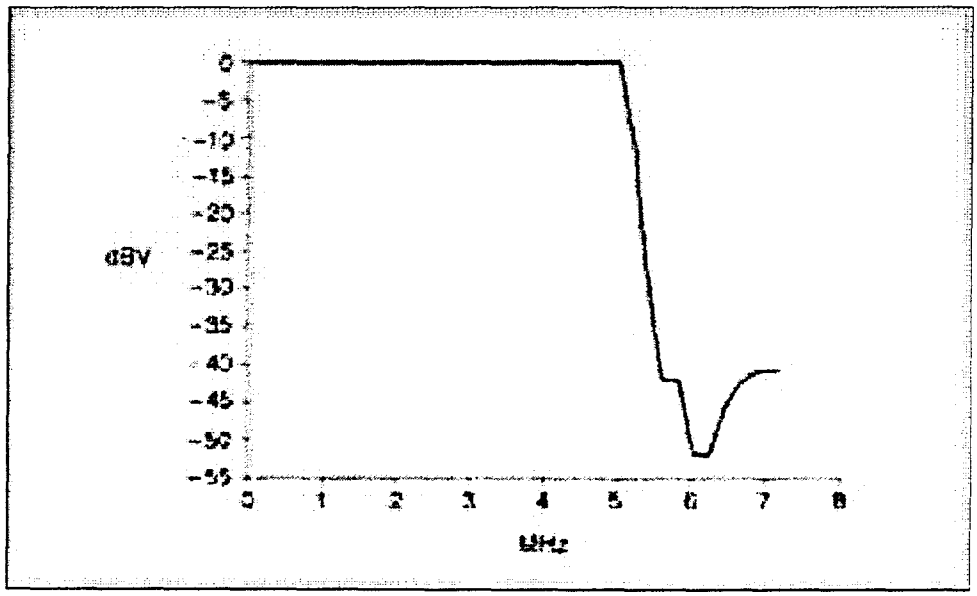
Measurement	Range	Accuracy	Test Signal
Line Time Distortion	0 to 40% of Bar	±0.2%	FCC or NTC-7 Composite
Pulse to Bar Ratio	10 to 125%	±0.7%	FCC or NTC-7 Composite
Short Time Waveform Distortion (IEEE 511)	0 to 25% SD	±0.5% SD	NTC-7 Composite
Chromiance Non-Linear Gain Distortion	5 to 35 IREE 20 IRE chroma) 45 to 160 IRE (80 IRE chroma)	±0.4 IRE	NTC-7 Combination
Chrominance Non-linear Phase Distortion	0 to 360 deg	±1.0 deg	NTC-7 Combination
Chrominance to Luminance Intermodulation	±50 IRE	±0.2 IRE	NTC-7 Combination
2T K-Factor	0 to 10% Kf	±0.3% Kf	FCC or NTC-7 Composite

VIRS MEASUREMENTS

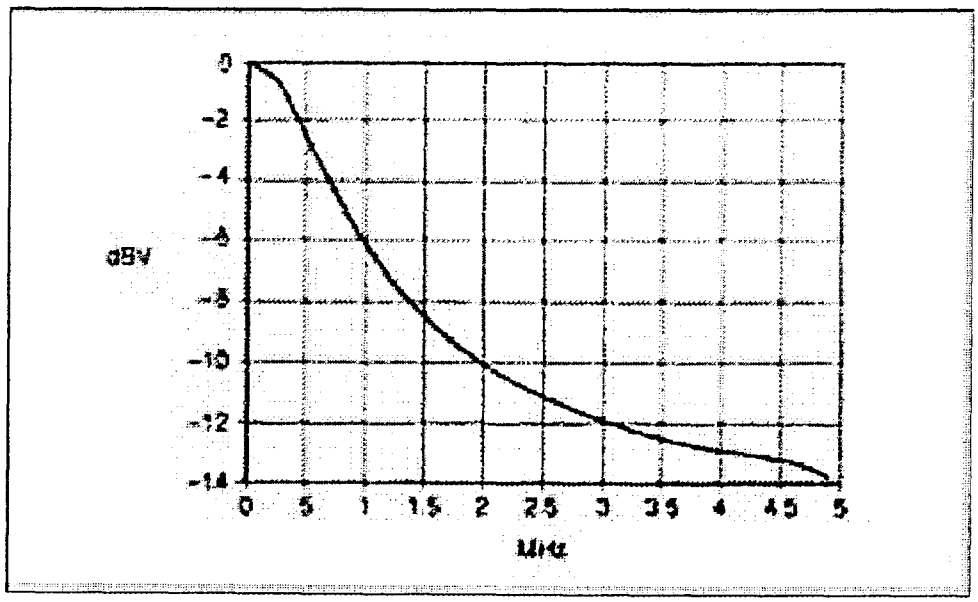
Measurement	Range	Accuracy	Test Signal
VIRS Setup (Reference Black)	-20 to 130% of Bar (-20 to J321 130 IRE when Bar is not used)	±0.2% (±0.5 IRE when Bar is not used)	VIRS
VIRS Chrominance Reference Amplitude	0 to 200% of burst amplitude (0 to 80% of Bar when burst is not used and 0 to 80 IRE when burst and bar are not used)	±1% (±0.1% when burst is not used and ±1 IRE when burst and Bar are not used).	VIRS
VIRS Chrominance Phase Relative to Burst	±180 deg	±0.5 deg	VIRS
VIRS Luminance Reference	30 to 100% of Bar (30 to 100 IRE when Bar is not used)	±0.2% (±0.2 IRE)	VIRS

SIGNAL-TO-NOISE RATIO MEASUREMENTS

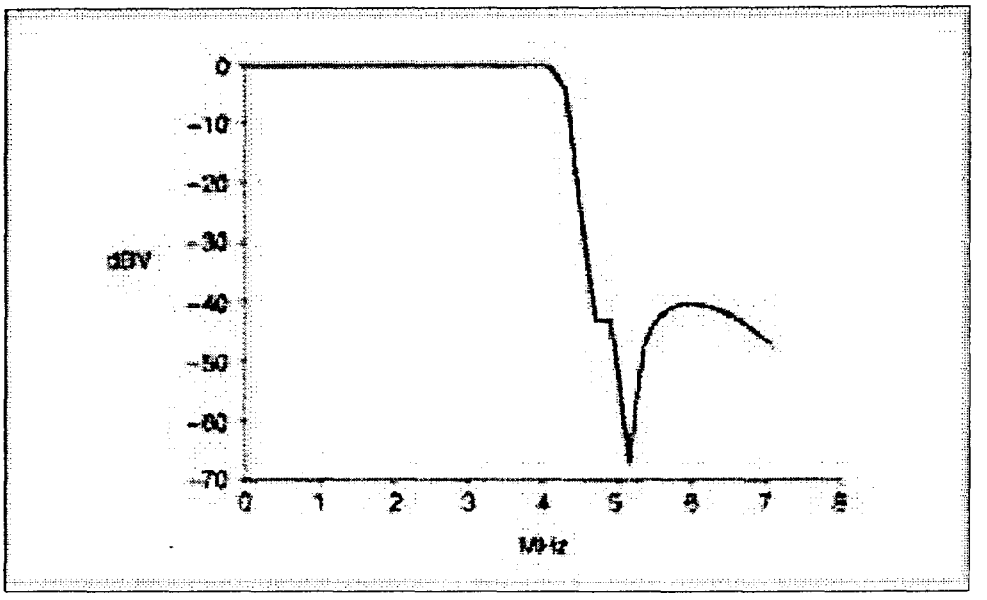
Measurement	Range	Accuracy	Test Signal
Unified Unweighted SNR	26 to 60 dB 61 to 70 dB	±1.0 dB ±2.0 dB	Quiet Line
Unified Luminance Weighted SNR	26 to 60 dB 61 to 70 dB	±1.0 dB ±2.0 dB	Quiet Line
NTC 7 Unweighted SNR	26 to 60 dB 61 to 70 dB	±1.0 dB ±2.0 dB	Quiet Line
NTC 7 Luminance Weighted SNR	26 to 60 dB 61 to 70 dB	±1.0 dB ±2.0 dB	Quiet Line
Periodic SNR	26 to 60 dB 61 to 70 dB	±1.0 dB ±2.0 dB	Quiet Line



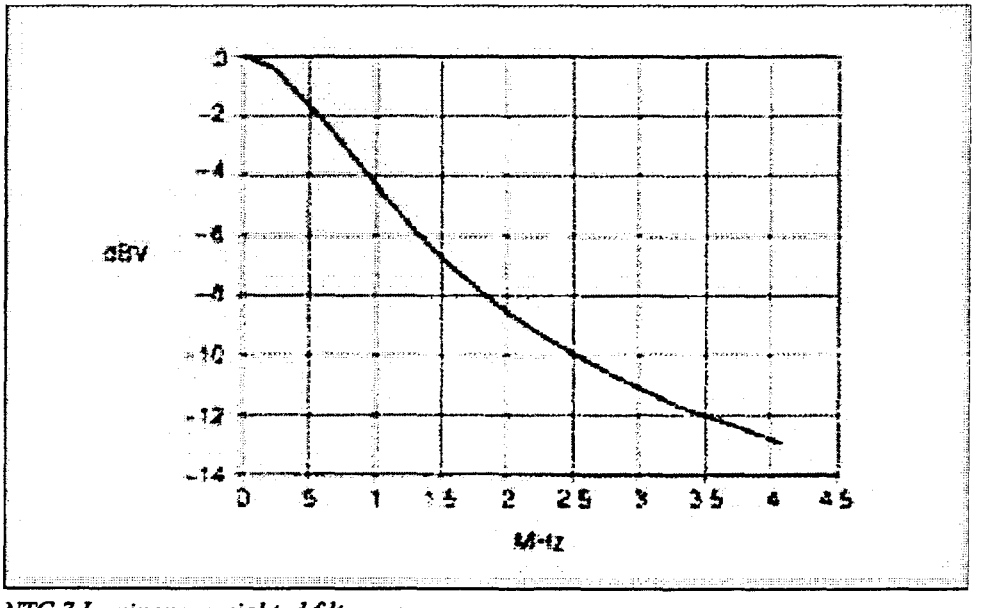
Unified Unweighted filter response curve per CCIR Recommendation 567.



Unified Luminance weighted filter response curve per CCIR Recommendation 567



NTC 7 Unweighted filter response.



NTC 7 Luminance weighted filter response.

MEASUREMENT METHODS - AUTO-MODE

The following paragraphs describe the measurement methods for each measurement. Each timing measurement method is written for the FCC method. If there is an RS-170A method for that same measurement, and the RS-170A method differs from the FCC method, the RS-170A requirement is enclosed within square brackets in the FCC description.

HORIZONTAL INTERVAL TIMING MEASUREMENTS

These timing measurements are made within the active picture area, averaging the results over 32 lines starting at line 50 and skipping 1-frame plus 5 lines for each successive sample (i.e., average over line 50 of first field, line 56 of second field, line 62 of the third field, etc.).

- **Breezeway Width:** Measured from the 10% point on the trailing edge of horizontal sync (nominally -4-IRE) to the leading half-amplitude point of the burst envelope.
- **Color Burst Width:** Measured from the leading half-amplitude point on the burst envelope [leading zero crossing of the first half-cycle of burst that exceeds 50% of burst amplitude] to the trailing half-amplitude point on the burst envelope [trailing zero crossing of the last half-cycle of burst that exceeds 50% of burst amplitude].
- **Front Porch Duration:** Measured from the 10% point on the trailing edge of setup (+4 IRE nominally) to the 10% [50%] point on the leading edge of sync (nominally -4 [20] IRE).
- **Horizontal Blanking Width:** Measured between the points on the leading and trailing edges of horizontal blanking that are at an amplitude of 10% [50%] of sync above blanking level (nominally +4 [+20] IRE).
- **Horizontal Sync Rise Time and Fall Time:** Measured between the 10% and 90% points on the leading and trailing edges of horizontal sync, respectively (nominally -4 IRE and -36 IRE).
- **Horizontal Sync Width:** Measured between the 10% [50%] points on the leading and trailing edges of horizontal sync (nominally -4 [-20] IRE).
- **SCH Phase:** Phase at the middle of burst relative to the 50% point on the sync leading edge.
- **Sync to Setup:** Measured from the 10% [50%] point on the leading edge of sync (nominally -4 [-20] IRE) to the point on the trailing edge of blanking that is equivalent to 10% of sync (nominally +4 IRE).
- **Sync-to-Start-of-Burst:** Measured from the 50% point on the leading edge of sync (nominally -20 IRE) to the leading zero crossing of the first half-cycle of burst that exceeds 50% of burst amplitude.
- **Sync-to-End-of-Burst:** Measured from the 10% point on the leading edge of horizontal sync (nominally -4 IRE) to the half-amplitude point on the trailing edge of the burst envelope.

VERTICAL INTERVAL TIMING

Equalizing Pulse Width: Measured between the 10% [50%] points on the equalizing pulse (nominally -4 [-20] IRE).

Serration Width: Measured between the 10% [50%] points of serration (nominally -4 [-20] IRE).

Vertical Blanking Width: Measured between the points on setup [active picture] at a level equal to 10% [50%] of sync amplitude (nominally +4 [+20] IRE), where setup [active picture] immediately precedes and follows the vertical blanking interval.

COLOR BAR MEASUREMENTS

Color Bar Amplitude Error: Measured as deviation of the peak-to-peak amplitude of each color bar from the nominal value for that color bar expressed as a percent of the nominal value. Six values reported.

Color Bar Phase Error: Measured as deviation of the phase of each color bar from the nominal phase for that color bar, relative to burst phase. Six values reported.

Color Bar Chrominance-Luminance Gain Ratio: Measured as ratio of chrominance level to luminance level of each color bar, relative to the nominal ratio for each color bar. Six values reported.

Color	Amplitude	Phase	C/L Gain Ratio
Yellow	67.36%	167.59 deg	1.0092
Cyan	94.74%	283.54 deg	1.8045
Green	89.04%	240.67 deg	2.0123
Magenta	89.04%	60.67 deg	2.8957
Red	94.74%	103.54 deg	4.2106
Blue	67.36%	347.59 deg	8.1652

FCC Color Bars Nominal Values
(Source: FCC Rule 73.699, Figure 14).

AMPLITUDE AND PHASE MEASUREMENTS (FCC OR NTC-7 COMPOSITE VITS)

- Bar Top: Measured as the ratio of the bar top to Zero Carrier amplitude to the blanking (at back porch) to the Zero Carrier amplitude. Result expressed as a percent of Max Carrier.
- Bar Amplitude: Measured from the reference blanking level (at back porch) contained within the test line to the level at the center of the bar.
- Burst Amplitude: VITS not required. Burst amplitude must be at least 10 IRE. Measured as peak-to-peak amplitude of the color burst at burst center.
- Chrominance-Luminance Delay Inequality (Relative Chrominance Time): Measured as the time difference between the luminance component and chrominance component of the modulated 12.5T pulse.
- Chrominance-Luminance Gain Inequality (Relative Chrominance Level): Measured as the peak-to-peak amplitude of the chrominance component of the modulated 12.5T-pulse.
- Differential Gain: Measured as the absolute amplitude difference between the smallest and largest staircase chrominance packets. Result expressed as a percent of the largest packet amplitude.
- Differential Phase: Measured as the largest difference in phase between any two staircase chrominance packets.
- Luminance Non-linear Distortion: Measured as the difference between the largest and smallest step amplitudes of the staircase at the center of each step. Result expressed as a percent of the largest step amplitude difference.
- Relative Burst Gain: Measured as the difference between the peak-to-peak amplitude of burst and the staircase chrominance packet located at blanking. Result expressed as a percent of the packet amplitude.
- Relative Burst Phase: Measured as the difference in phase between the color burst and the staircase packet located at blanking.
- Sync Amplitude: Measured from the tip of the horizontal sync pulse to blanking level.
- Blanking Level: Measured as the ratio of the blanking (at back porch) to Zero Carrier amplitude to the sync tip to Zero Carrier amplitude. Result expressed as a percent of Max Carrier.
- Sync Variation: Measured as the peak-to-peak variation of the horizontal sync pulse amplitude within every third line of a field.
- Blanking Variation: Measured as the peak-to-peak variation of the blanking level within every third line of a field.

FREQUENCY RESPONSE MEASUREMENTS (FCC MULTIBURST OR NTC-7COMBINATION VITS)

- Multiburst Flag Amplitude: Measured from back porch blanking to the center point of the flag top.
- Multiburst Amplitude: Measured as the peak-to-peak amplitude of each of the multiburst

packets. Six results reported.

WAVEFORM DISTORTION MEASUREMENTS (FCC OR NTC-7 COMPOSITE VITS)

- **Line Time Distortion:** Measured as the peak-to-peak amplitude change of the bar top, excluding the first microsecond and the last microsecond.
- **Pulse-to-Bar Ratio:** Measured as the peak amplitude of the 2T pulse, expressed as a percent of the bar amplitude.
- **Short-Time Waveform Distortion:** Measured as a weighted function of time, the result is the peak deviation from flatness within 1 microsecond of the center of a bar transition. ANSI/IEEE Std.-511-1979, Section 4.4, Appendix B.
- **Chrominance Non-linear Gain Distortion:** Measured as the peak-to-peak amplitude of the first (nominally 20 IRE) and last (nominally 80 IRE) chrominance packets in the 3-level chrominance signal, referenced to the peak-to-peak amplitude of the middle packet (nominally 40 IRE).
- **Chrominance Non-linear Phase Distortion:** Measured as the difference between the largest and the smallest deviation in phase among the 3-level chrominance test signal subcarrier packets.
- **Chrominance to Luminance Intermodulation:** Measured using the 3-level chrominance test signal. Result is the maximum amplitude departure of a filtered part of the luminance pedestal from a part of the pedestal upon which no subcarrier has been superimposed.
- **2T Pulse K-factor:** Measured as the greatest weighted amplitude of a positive-going or negative-going echo-term half-wave which is within one microsecond before the 2T pulse leading edge half-amplitude point or within one microsecond after the 2T pulse trailing edge half-amplitude point. Result expressed as a K-factor which is the ratio of the weighted amplitude of the echo-term half-wave to the sampled amplitude of the 2T pulse.

VIRS MEASUREMENTS VIRS SETUP (REFERENCE BLACK):

- **VIRS Chrominance Reference Amplitude:** Measured from the blanking level included in the test signal to setup level.
- **VIRS Chrominance Phase Relative to Burst:** Measured as the amplitude of the VIRS chrominance packet, expressed as a percent of burst (or percent of bar if no burst).
- **VIRS Luminance Reference:** Measured as the difference between the VIRS chrominance packet phase and color burst phase.

SIGNAL-TO-NOISE RATIO MEASUREMENTS

- Measured from the blanking level included in the test signal to luminance reference level (nominally 50 IRE).
- **Unweighted SNR:** Measured as the ratio of bar amplitude to the unweighted rms amplitude of the noise on a quiet line.
- **Luminance Weighted SNR:** Measured as the ratio of bar amplitude to the luminance weighted rms amplitude of the noise on a quiet line.
- **Periodic SNR:** Measured as the ratio of bar amplitude to the peak-to-peak value of the periodic noise.

OUT-OF-SERVICE MEASUREMENTS

- **Long Time Distortion:** Measured as the peak overshoot and settling time in a flat field test signal switched from 10% to 90% APL in less than 10 µsec.
- **Field Time Distortion:** Measured as the peak-to-peak amplitude change of the 100 IRE field squarewave top. The first and last 250 µsec are excluded. Expressed as a percent of the field squarewave amplitude.

CE

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Exhibit C

The Influence of Trees on Television Field Strengths at Ultra-High Frequencies

Howard T. Head

THE INFLUENCE OF TREES ON[1] TELEVISION FIELD STRENGTHS AT ULTRA-HIGH FREQUENCIES

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Introduction

One of the more serious aspects of the problem of providing television service at the ultra-high frequencies has been the failure in many instances to obtain r.f. field strengths within the service areas as high as predicted by classical propagation theory. It has been generally appreciated that rough terrain and heavy vegetation have depressing effects on the received signal. The recognition of the effects, however, has been mainly qualitative, with no clear understanding of the absolute or relative magnitudes of the respective losses.

Recent work by LaGrone[2] at the University of Texas and others has provided a reasonable quantitative assessment of the influence of rough terrain on the received signal[3]. However, even after due allowance has been made for the reduction of signal caused by rough terrain, the observed median field strength is often still substantially below that predicted by classical theory. LaGrone, in his report to the Television Allocations Study Organization, recommends that smooth-earth predictions at the ultra-high frequencies (470 mc to 890 mc for television service) be reduced by 22 decibels to provide basic curves from which further departures due to terrain irregularities are predicted.

Experimental Program

To determine how much UHF signal reduction might be ascribed to the effects of trees, a program of field strength measurements was undertaken in the vicinity of Salisbury, Maryland, during December 1958 and January 1959. This area was selected (see Figure 1) because the terrain is very flat, because new topographic maps showing woodland cover were available, and because a television transmitting station (WBOC-TV) was in operation with a transmitting antenna height (620 feet above terrain) reasonably characteristic of stations in regular operation. The transmitter

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/1 This work was sponsored by the Association of Maximum Service Telecasters, Inc.

/2 A.H. LaGrone, "Forecasting Television Service Fields", FINAL REPORT TASO/UT CONTRACT, December 31, 1958

/3 Other references dealing with terrain losses are listed in the bibliography.

operates on television channel 16, which occupies the frequency band from 482 mc to 488 mc. The visual and aural carrier frequencies are 483.26 mc and 487.76 mc, respectively. The radiated power is approximately 20 kw, essentially omnidirectional in the horizontal plane.

Field strength measurements on the WBOC-TV signal were made at locations selected to provide transmission under varying conditions over, through, and around woods. At each location selected for measurement, the field strengths were measured using a short mobile run in accordance with the measuring technique specified by Panel 4 (Propagation Data) of the Television Allocations Study Organization. In a few instances where the mobile run was impractical, a "cluster" of spot measurements was substituted. The use of the mobile run or "cluster" technique introduces an averaging process which tends to smooth out small-area variations caused by standing wave patterns or other local influences.

All of the measurements were made with a receiving antenna height of 30 feet above ground. The details of the equipment and technique utilized in making these measurements have been described in a previous article/4.

Measurements were made over transmission paths which fall into three general categories:

(a) Unobstructed ray paths between transmitting and receiving antennas;

(b) Ray paths obstructed by groups of trees sufficiently small that the signal would be propagated principally through, rather than around, the trees (these are referred to as "thin screens" of trees); and

(c) Ray paths obstructed by groups of trees sufficiently large that the signal would be propagated principally around, rather than through, the trees (these are referred to as "thick screens" of trees).

Measuring locations in this last category were chosen so that the obstructing mass of trees occurred at varying distances from the receiving antenna in the direction of

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/4 H. T. Head, "Measurement of Television Field Strength", ELECTRICAL ENGINEERING, Vol. 77, No. 4, pp. 298-302, April 1958.

the transmitting antenna. The distance from the receiving antenna to the woods is referred to as the "clearing depth" (see Figure 3).

Discussion of Results

A survey of the literature reveals only scant references to the effect of trees and foliage on the received signal at the ultra-high frequencies. Trevor/5 in the United States and Saxton and Lane/6 in Great Britain have published results showing the attenuation of the signal when the transmission path is entirely through vegetation. Some classified NDRC reports from World War II include similar data. The available data are reasonably consistent and show relatively severe attenuation of signals at these frequencies when the transmission path lies entirely through trees and underbrush. The conclusions, as summarized by Saxton and Lane, are shown in Figure 2.

Measurements were made at 13 locations in the Salisbury area of the attenuation of the signal in passing through thin screens of trees ranging in thickness from 8 meters to 480 meters. The results of these measurements are in reasonably good agreement with the conclusions of Saxton and Lane, but the rate of attenuation shows a decreasing trend with increasing woods thickness. This variation is probably due principally to the fact that the typical television transmission path is basically different from that for the condition where both the transmitting and receiving antennas are surrounded by trees.

In the latter situation, the entire ray path must pass through the obstructing vegetation. For typical television transmission, however, only a small part of the transmission path may pass through trees and underbrush. The transmitting antenna is usually several hundred feet high, and only within a few miles of the receiving antenna is the signal obliged to cope with trees and underbrush near the ground. This is illustrated in Figure 3, which shows a typical ray path for transmission between television transmitting and receiving antennas. For a path such as shown, substantial amounts of the signal may be diffracted over and around the trees. The presence of the diffracted signal is most noticeable when the vegetation is so dense as to reduce the signal transmitted through the trees to a very low value.

/5 B. Trevor, "Ultra-High Frequency Propagation Through Woods and Underbrush", RCA REVIEW, pp. 90-92, July 1940

/6 J.A. Saxton and J.A. Lane, "VHF and UHF Reception - Effects of Trees and Other Obstacles", WIRELESS WORLD, Vol 61, No. 5, pp. 229-232, May 1955

The first measurements made in the Salisbury area were intended to permit a determination of the signal arriving at the receiving antenna in terms of the attenuation in passing through various thicknesses of woods. Examination of the first results, however, showed little correlation with woods thickness, and a comparison with the Saxton and Lane curve (Figure 2) revealed that the thicknesses being employed were so great that the signal arriving through the woods should be well below the noise level of the measuring equipment; nevertheless, measurable signals were being received. A further study of the measurements showed that the relative signal levels were lowest when the receiving antenna was closest to the edge of the woods between the transmitting and receiving antennas, increasing as the clearing depth (see Figure 3) increased.

A preliminary analysis showed the signal to increase approximately in proportion to the logarithm of the clearing depth for clearing depths greater than approximately 0.01 mile, but at very close distances to the woods the signal level appeared to be more or less unrelated to the clearing depth. This is illustrated by Figure 4, which shows the difference between the smooth-earth predictions and the actual observations plotted versus the logarithm of the clearing depth. The straight line is a least-squares fit to the data points beyond 0.01 mile. The standard deviation from the line is 4.1 decibels.

Comparison with Diffraction Theory

The basic theory of the diffraction of electromagnetic energy around the edge of a partially or completely opaque object is well established. Particular solutions, however, have been obtained only for a number of special cases, and the typical practical problem may bear little resemblance to the idealized situations for which theoretical solutions have been derived. Also, it is often difficult to foretell from the geometry of the practical case which of the particular theoretical solutions represents the model most closely resembling actual transmission conditions.

The Salisbury data were separated into two groups. In the first group were the thin screen measurements, in which it appeared that the received signals represented so complex a combination of transmitted and diffracted signals that they would have little value in a diffraction analysis. The remaining measurements, consisting of the thick screen measurements and unobstructed ray path measurements, were

grouped together and tabulated. For each observation, there was determined the depression of the measured field below the smooth-earth value (Δ_{SE}), the depression of the field below the free-space value (Δ_{FS}), and the ratio of the obstruction of the trees in the first Fresnel zone to the radius of the zone at the point of maximum obstruction (H/H_o). Graphs of these values were plotted and compared with attenuation curves representing various modes of diffraction/7,8.

A plot of Δ_{SE} versus H/H_o does not exhibit particularly good correlation with the theoretical diffraction curves. However, a plot of Δ_{FS} versus H/H_o shows that for Fresnel zone clearances greater than about -1.0 the points tend to fall in the general region of the theoretical curves for diffraction around a smooth sphere. Figure 5 is a plot of this relationship showing a comparison with theoretical diffraction around a smooth spherical obstacle for a reflection co-efficient R = -1 and a value of Bullington's parameter M of M = 300.

The parameter M is a function of transmitting and receiving antenna heights, frequency and radius of the spherical obstacle. For the heights and frequency at Salisbury, a value of M = 300 corresponds to a smooth sphere having a radius of 24 miles. The standard deviation of the observed values from the theoretical curve is 3.4 db for Fresnel zone clearances in excess of -1.0.

The observed data were next compared with diffraction theory making the assumption that the trees exhibit some sort of "edge effect", due to the thinness of the upper branches, the small diameter of the top of the trunks, or other causes. Most of the tree heights for the transmission paths at Salisbury had been determined by actual measurements with a Matthews Teleheight, and the average tree heights were approximately 55 feet. The actual tops of the trees were thus some 25 feet above the receiving antenna height of 30 feet above ground.

The values of H/H_o were redetermined assuming the existence of an "edge effect" of 10 feet; this would result in an apparent average height of the trees of 45 feet above

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/7 K. Bullington, "Radio Propagation Fundamentals", BELL SYSTEM TECHNICAL JOURNAL, Vol. 36, No. 3, pp. 593-626, May 1957

/8 A. I. Kalinin, "Approximate Methods of Computing the Field Strength of Ultra Short Waves with Consideration of Terrain Relief", RADIOTEKHNIKA, Vol. 12, No. 4 pp. 13-26, 1957

ground, or 15 feet above the receiving antenna. The redetermined values of H/H_o were then plotted against Δ_{FS} and the plot compared with the theoretical diffraction curves.

Figure 6 shows a comparison of the observed values for the redetermined values of H/H_o with the theoretical smooth-sphere diffraction prediction for M = 50. This value of M corresponds to diffraction around a sphere having a radius equal to 4/3 of the earth's radius, the value customarily assumed in classical theory for propagation through a standard atmosphere. The standard deviation of the observed values from the theoretical curve is 2.9 db for Fresnel zone clearances greater than -0.6.

It will be noted from Figure 6 that the attenuation is substantially less than predicted on the basis of smooth-sphere diffraction for Fresnel zone clearance less than approximately -0.6. These values of Fresnel zone clearance represent locations where the receiving antenna was very close to the obstructing mass of trees, generally within 100 feet or less. In several instances, the receiving antenna was within 10 feet of the nearest edge of the woods.

In this region, the attenuation exhibits little correlation with any of the parameters influencing the other fields. It appears likely that the field received near the edge of the woods arrives at the receiving antenna principally through the tops of the woods and over a number of irregular paths. In making this portion of the measurements, it was frequently observed that the receiving antenna did not exhibit any clear maximum and minimum as the antenna was rotated; in many instances it was not possible to identify the direction toward the transmitter from the orientation of the receiving antenna. The signal arriving under these conditions has been referred to as the "leakage field" (F_ℓ) because it appears to leak through the tops of the trees, often in a rather erratic fashion.

The measurements which were considered to represent principally leakage field were analyzed for any evident trends. An examination of eight observations of leakage field at distances ranging from 12.0 miles to 22.5 miles from the transmitter indicated the average signal level

below the calculated smooth-earth field to be more or less independent of distance. For these eight points, the average depression of the field below the smooth-earth field was approximately 30 db, with a standard deviation of 3.3 db.

Extension of Theory

These observations and conclusions provide a basis for predicting loss of UHF signal strength where the loss is due primarily to the effects of trees. Consider a transmission path such as shown in Figure 7a. Between the transmitting antenna and the first woods at the distance D_1 there is no obstruction, and the received fields in this region are those predicted by smooth-earth theory. Beyond D_1, in the woods, the received signals are primarily those arriving through the woods, and the attenuation increases rapidly with woods thickness until the leakage field level is reached (D_2). The attenuation cannot exceed that corresponding to the leakage level, and thus any additional woods thickness does not result in further depression of the signal.

Beyond the distance D_3, where the far edge of the woods is reached, the received signals recover with distance in an approximately logarithmic fashion until the clearing depth is sufficient that the smooth-earth values are once again approached. This logarithmic recovery, which is noted in Figure 4, can be shown to follow as a consequence of diffraction; the relationship is determined by the geometry associated with the distance between transmitter and receiver.

This model of the behavior of the field permits drawing some interesting conclusions. First, in an area completely covered with trees or essentially so, the received signal would be largely governed by the leakage level. This level is probably a function of frequency and also of the type of vegetation. If this latter is the case, as seems likely, the leakage fields would be expected to be lower in the spring and summer than in the fall and winter. It seems probable that the relationship of the leakage field to the frequency would be similar to that for attenuation in passing through thin screens of trees as shown in Figure 2.

If the forest cover is less than 100%, some receiving locations will be closely surrounded by trees and others partly in the clear. Theoretical models of the type shown in Figure 7b were set up, and the effects

of various sequences of woods and clearing were determined on the basis of the processes suggested. These studies showed that the average attenuation in an area with P_f per cent forest cover, in which the leakage field is denoted by F_ℓ, cannot be less than $P_f F_\ell/100$ for any sequences of woods and clearing reasonably to be expected. For unfavorable sequences, the attenuation may be higher than this value, but an upper limit of attenuation is set by the relationship between the decay and recovery characteristics shown in Figure 7b. The average attenuation as a function of per cent forest cover based on this model of the behavior of the field is shown in Figure 8. The straight line corresponds to the least attenuation of the signal for the most favorable sequence of woods and clearing, and the dashed line the highest attenuation to be expected for the most unfavorable sequence for a given percentage of forest cover. The dotted line shown in Figure 8 is an average attenuation curve falling between the two limits.

Conclusions

Using Figure 8, an estimate can be made of the average attenuation of the UHF signal due to the effect of trees, provided that an estimate of the percentage of forest cover can be made. Although some modifications will probably be required for other frequencies and for vegetation under other conditions, it can be seen that the average attenuation due to the trees is on the order of the 22 decibels below smooth-earth values employed by LaGrone. It appears likely, based on these findings and the model of attenuation derived from them, that forest attenuation may be one of the most significant factors responsible for the average loss in signal at the higher frequencies.

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(The numbers refer to the numbered footnotes in the article)

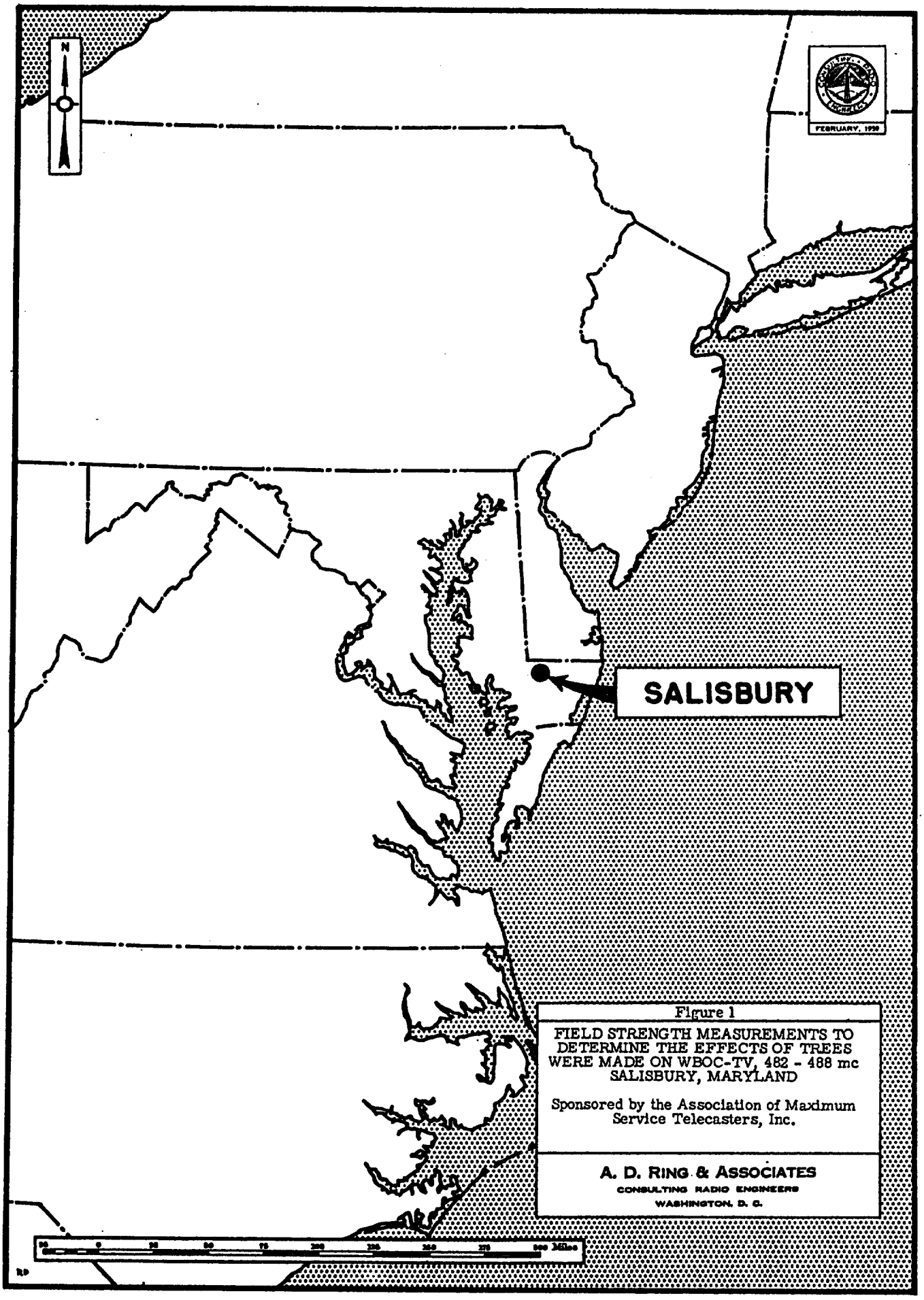

Figure 1

FIELD STRENGTH MEASUREMENTS TO DETERMINE THE EFFECTS OF TREES WERE MADE ON WBOC-TV, 482 - 488 mc SALISBURY, MARYLAND

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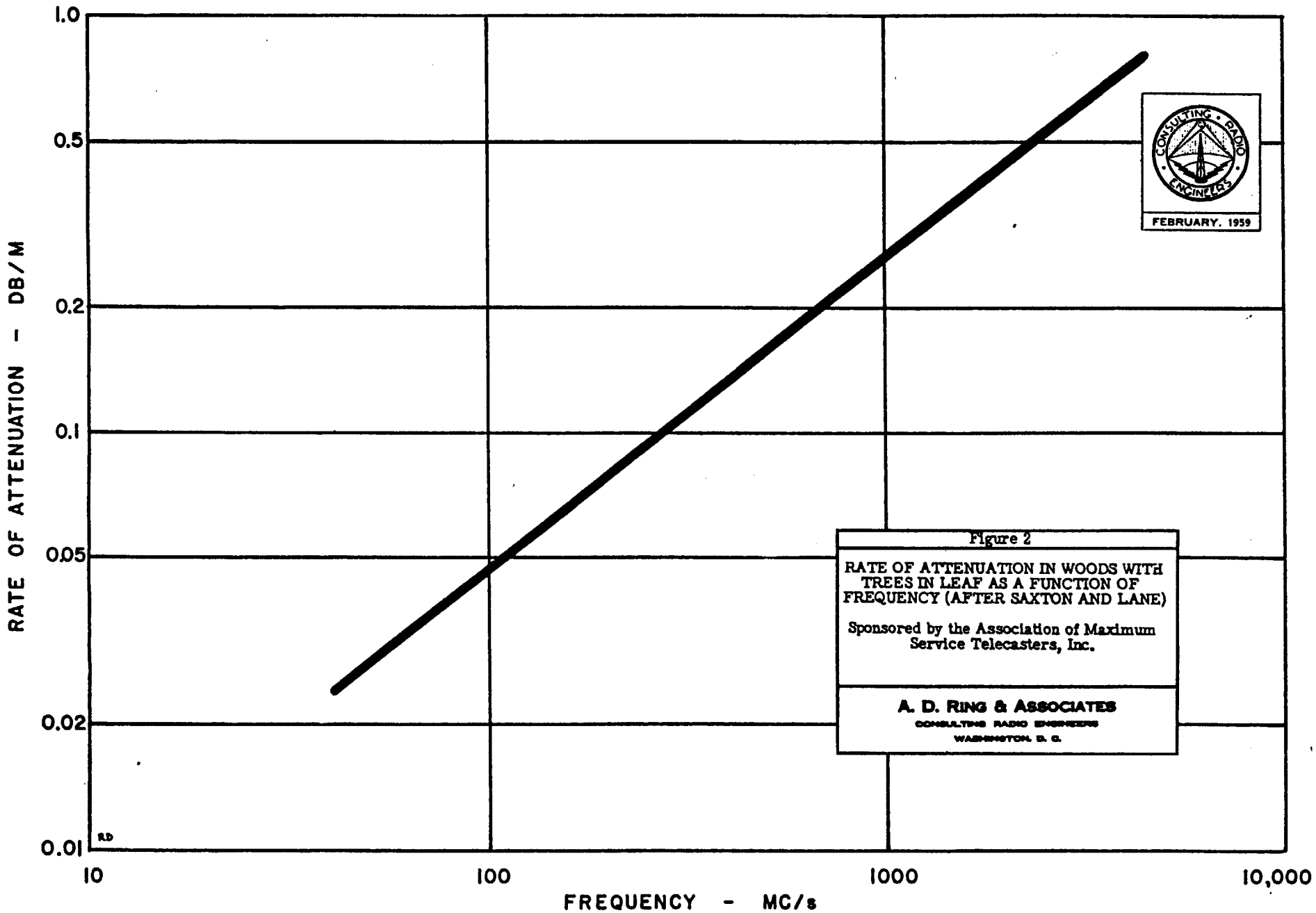

Figure 2

RATE OF ATTENUATION IN WOODS WITH TREES IN LEAF AS A FUNCTION OF FREQUENCY (AFTER SAXTON AND LANE)

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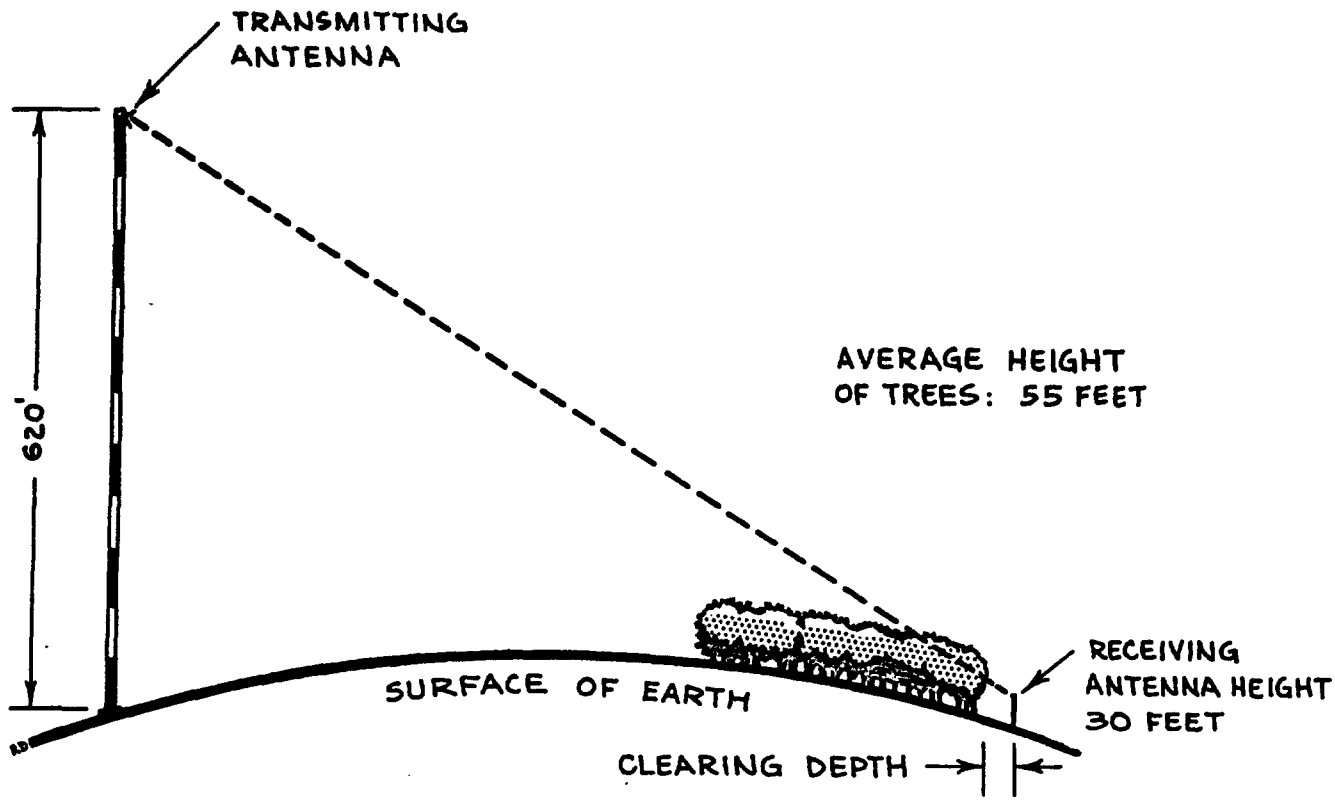

Figure 3

THE TYPICAL TELEVISION TRANSMISSION PATH IS BASICALLY DIFFERENT FROM THAT WHERE BOTH TRANSMITTING AND RECEIVING ANTENNAS ARE SURROUNDED BY TREES

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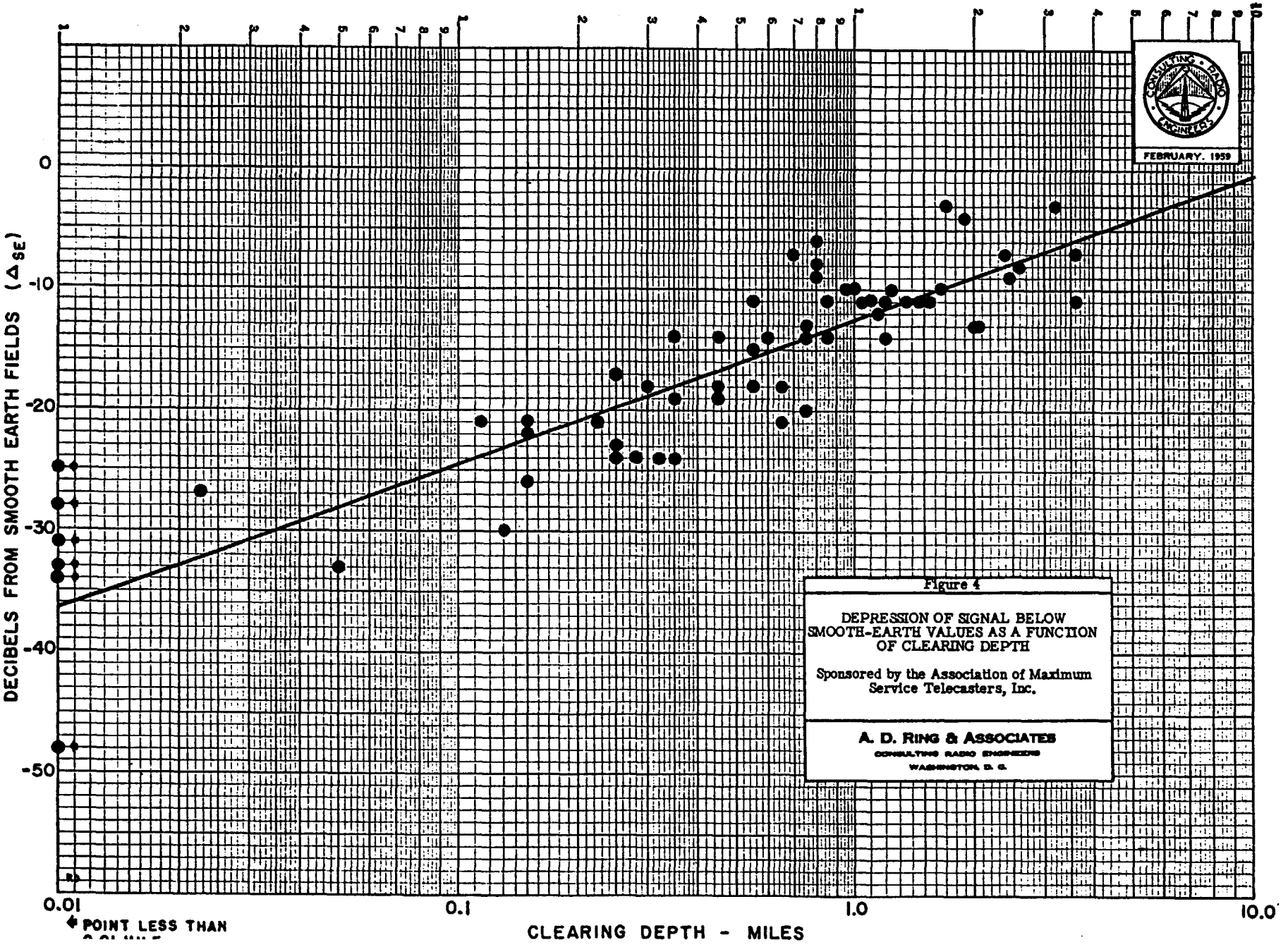

Figure 4

DEPRESSION OF SIGNAL BELOW SMOOTH-EARTH VALUES AS A FUNCTION OF CLEARING DEPTH

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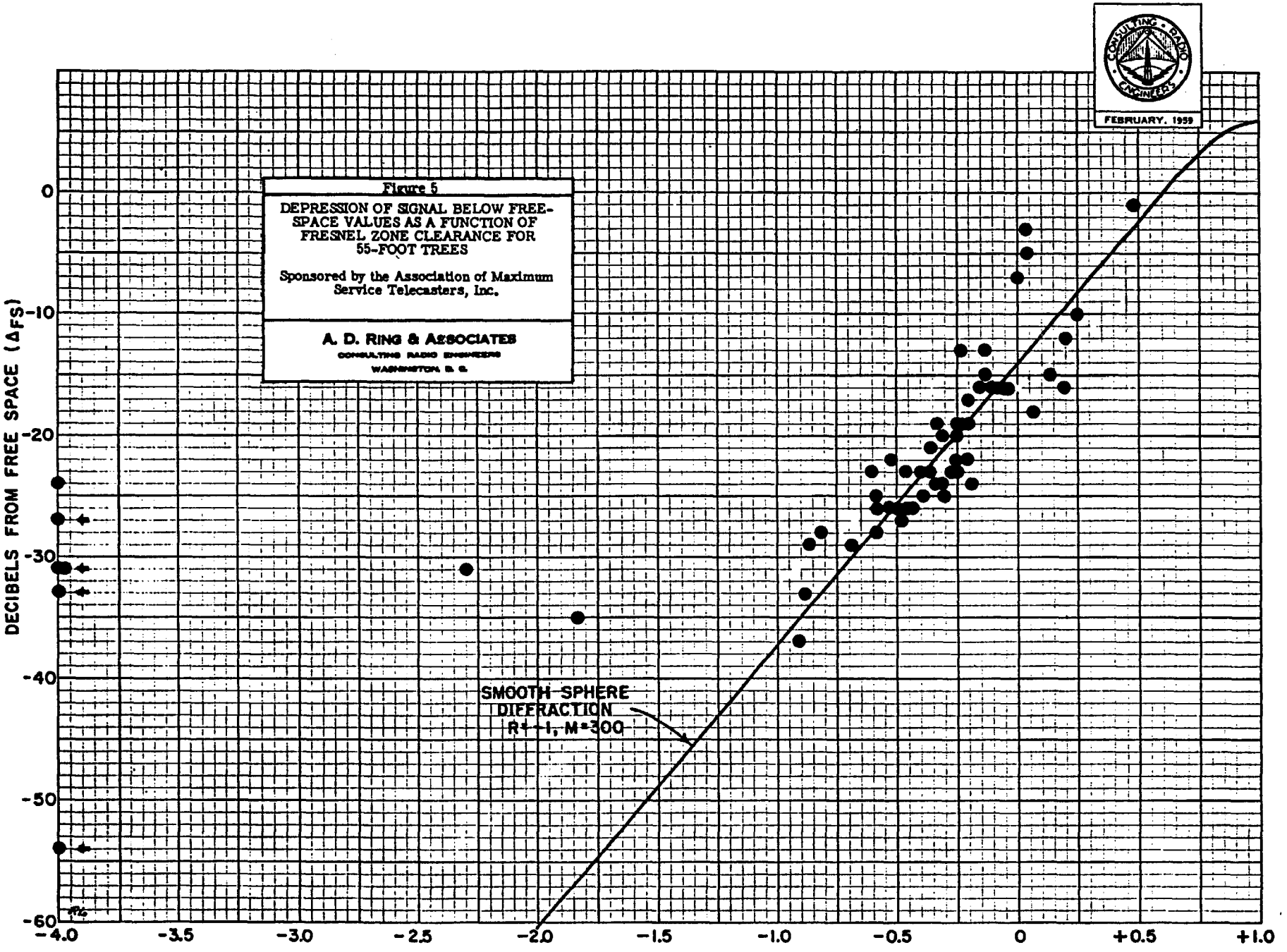

Figure 5

DEPRESSION OF SIGNAL BELOW FREE-SPACE VALUES AS A FUNCTION OF FRESNEL ZONE CLEARANCE FOR 55-FOOT TREES

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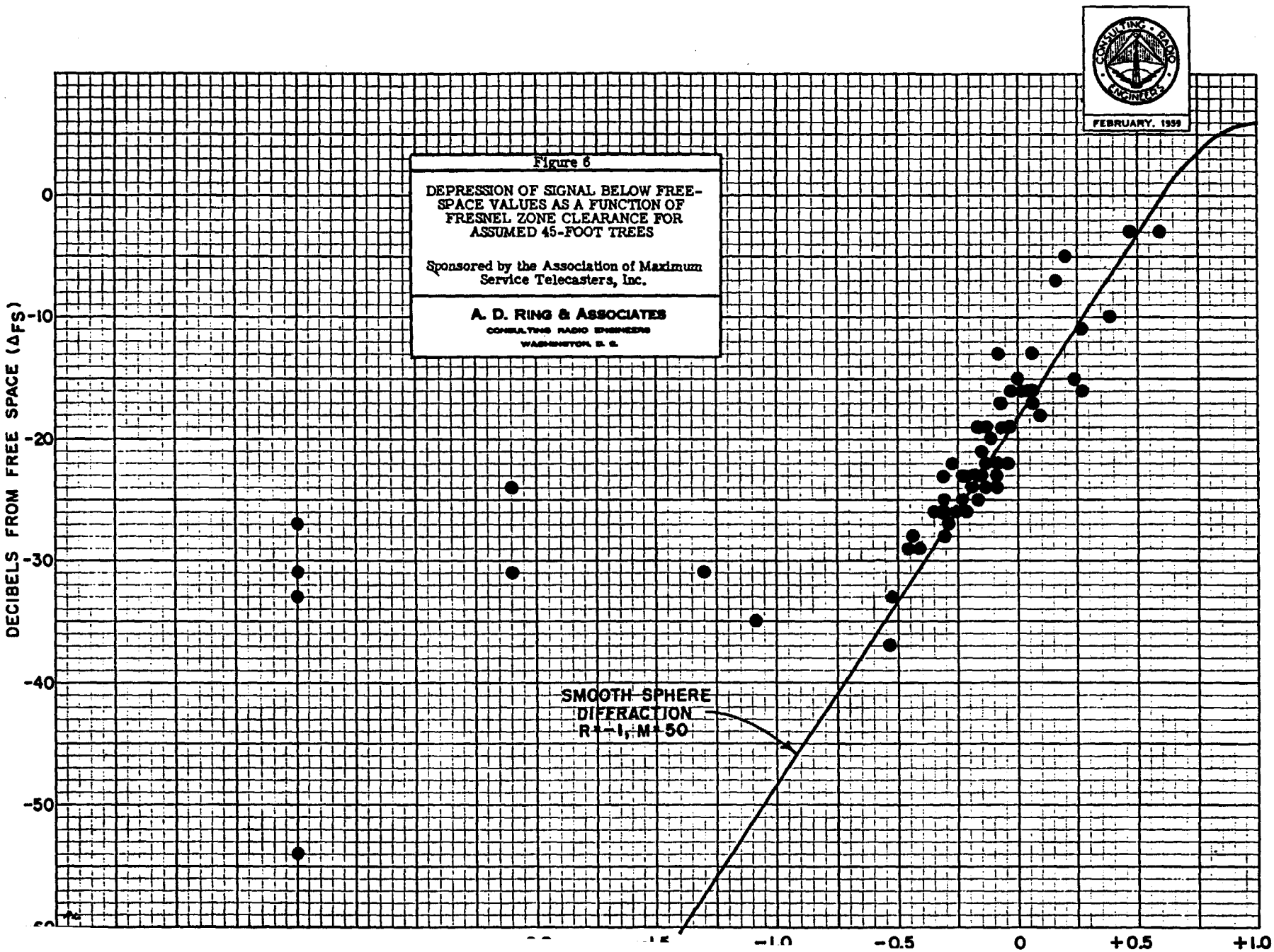

Figure 6

DEPRESSION OF SIGNAL BELOW FREE-SPACE VALUES AS A FUNCTION OF FRESNEL ZONE CLEARANCE FOR ASSUMED 45-FOOT TREES

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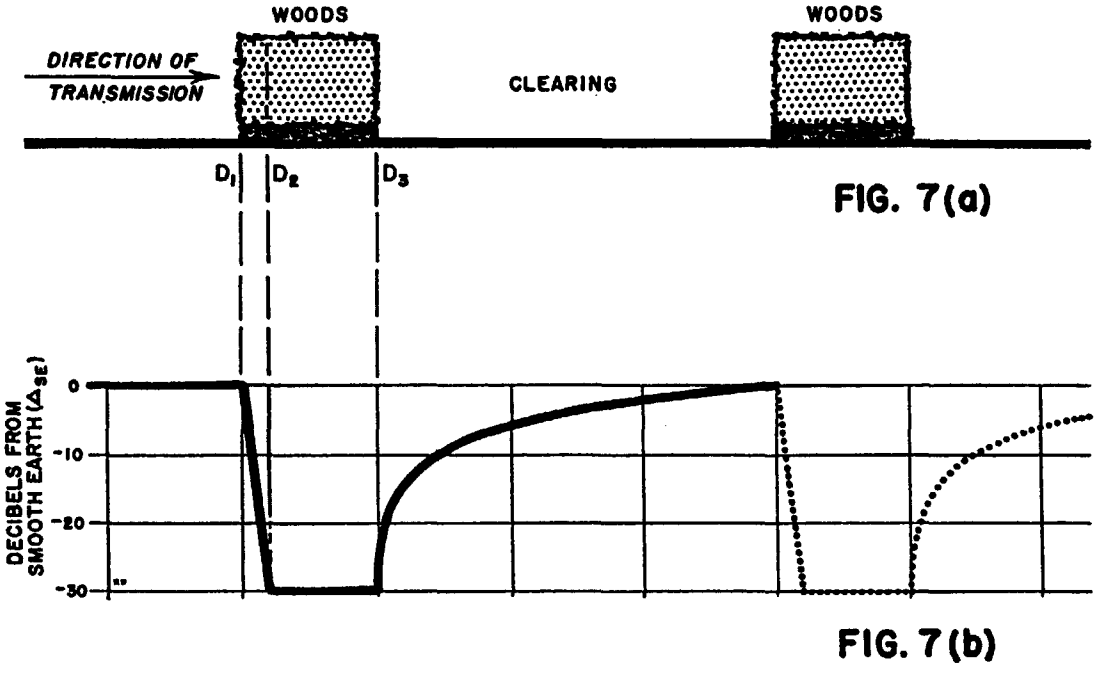

Figure 7

(a) MODEL OF WOODS-AND-CLEARING FOR ESTIMATING AVERAGE WOODS ATTENUATION

(b) DEPRESSION OF SIGNAL BELOW SMOOTH-EARTH VALUES VERSUS DISTANCE FOR THE MODEL OF FIGURE 7(a)

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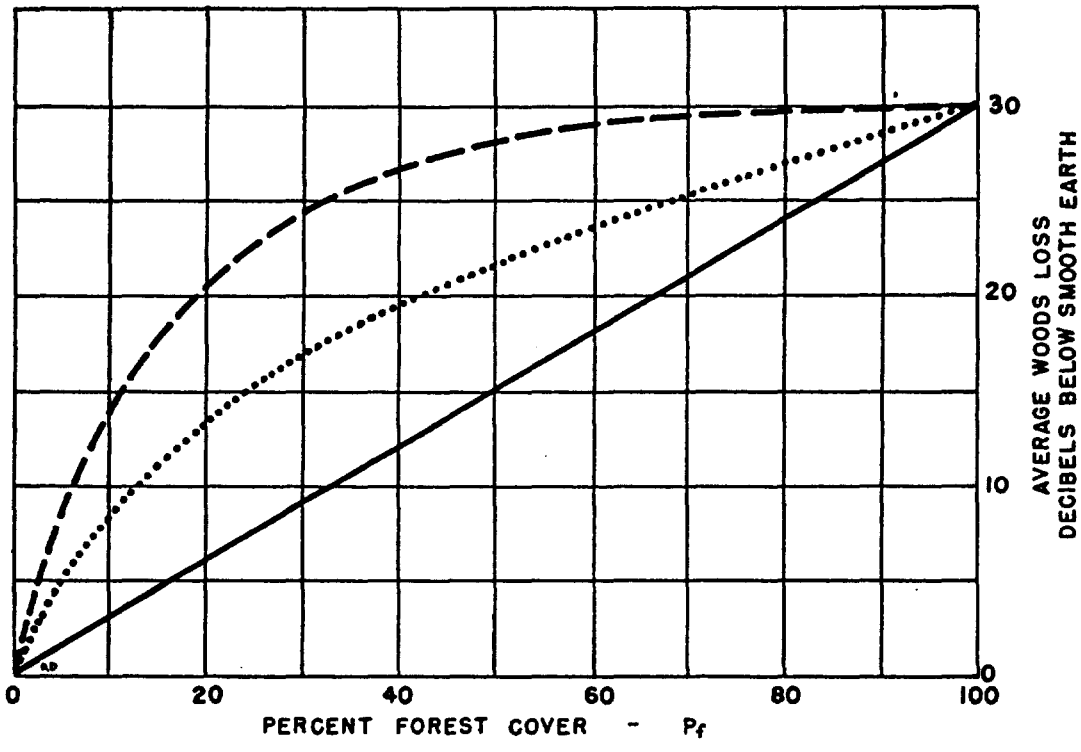

Figure 8

ESTIMATED AVERAGE SIGNAL DEPRESSION BELOW SMOOTH-EARTH VALUE AS A FUNCTION OF PERCENTAGE FOREST COVER P_f

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