19940011569

N94-16042

PROPAGATION-RELATED AMT DESIGN ASPECTS AND SUPPORTING EXPERIMENTS

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1. Introduction

The ACTS Mobile Terminal (AMT) is presently being developed with the goal of significantly extending commercial satellite applications and their user base. A thorough knowledge of the Ka-band channel characteristics is essential to the proper design of a commercially viable system that efficiently utilizes the valuable resources. To date, only limited tests have been performed to characterize the Ka-band channel and they have focused on the needs of fixed terminals. (See for example [1,2] as well as the articles in these proceedings.) As part of the value of the AMT as a Ka-band test bed is its function as a vehicle through which tests specifically applicable to the mobile satellite communications can be performed. The exact propagation environment with the proper set of elevation angles, vehicle antenna gains and patterns, roadside shadowing, rain and Doppler is encountered. The ability to measure all of the above, as well as correlate their effects with observed communication system performance, creates an invaluable opportunity to understand in depth Ka-band's potential in supporting mobile and personal communications. This paper discusses the propagation information required for system design, the setup with ACTS that will enable obtaining this information, and finally the types of experiments to be performed and data to be gathered by the AMT to meet this objective.

2. Experimental Setup

The AMT experimental setup with ACTS is shown in Figure 1. To support the FDMA architecture adopted (at least in the earliest experiments), an unmodulated pilot is transmitted from the fixed station to the AMT. This pilot is used by the mobile terminal for antenna tracking, as a frequency reference for Doppler correction and pre-compensation, and in measuring rain attenuation. For system efficiency, a pilot is transmitted only in the forward direction; i.e., from the fixed to the mobile terminal. Hence, in the AMT system setup two signals will exist in the forward direction, the pilot and the information link which could be voice or data. In the return direction (mobile to fixed) only the information channel (commonly referred to as the data channel) is transmitted. The data rate is selectable among 2.4, 4.8 and 9.6 kbps depending on channel conditions. A separate higher rate of 64 kbps will also be supported but under restricted link conditions.

Consistent with a Ka-band test bed approach, the AMT links have been designed to maximize utilization of the available ACTS resources to support as wide an array of channel measurements as possible. This is reflected in the link budgets of Table 1. ACTS was designed to support high data rate communications; as a result, even with the lowest TWT drive levels in the HBR-LET, the single user forward link has ample margin. This margin can be utilized to investigate the deleterious effects of the 20 GHz channel by permitting signal tracking through 15 - 20 dB of attenuation. Thus the range of channel impairments of practical interest can be studied with the AMT. (The different measurements will be discussed in Section 4.) In contrast to the forward link, the need to minimize radiation hazard in the neighborhood of the vehicle and practical limits on amplification in the user unit lead to a modest margin on the return link under normal operation. This is evidenced in Table 1. Nevertheless, under restricted experimental conditions this margin could be boosted by up to 10 dB. Hence 30 GHz propagation investigations initiated at the mobile terminal will cover channel effects of up to 10-15 dB of attenuation.

To support an extensive system/channel data gathering campaign, the AMT experimental setup will be equipped with a state of the art data acquisition system (DAS). The DAS will be capable of capturing and recording up to half a Mbyte/s of channel and system information. In addition, it will record half a Mbyte/s of synchronized video information from a camera designed to observe the physical link. It was learned from MSAT-X experience that one of the most painstaking (and time consuming) aspects of experiment analysis is correlation of the gathered data with the channel that was encountered. Not only is keeping track of the various propagation environments hard to do, but also identifying the events that result in peculiar data is practically impossible. The camera will be mounted on a slave platform that follows the pointing of the AMT antenna. The camera platform will be located near the rear of the van outside the field of view of the antenna. In addition to the video, experimenters' voices will be recorded on the DAS and synchronously time tagged for easy logging and retrieval of comments. Thus, a multitude of data types augmented with synchronized video and audio annotation will be available to the post experiment analyst. To support the transfer of the data to analysis workstations, either the compact tapes will be duplicated at the workstations or an Ethernet interface will be included in the DAS. To complement all of the above, the DAS will have substantial real time and near real time analysis and display capabilities. These are primarily intended to assist the experimenters in the field. They can, however, serve as starting points for the more detailed analysis that will follow.

At present a six month initial experimentation phase with ACTS has been planned. From March to September of 1993 mobile experiments will be performed using the AMT van. Another set of experiments will be performed using the sedan; however, the sedan will not be equipped with a DAS and will therefore be more suited to subjective quality tests. This phase is currently planned for 1994.

3. Channel Information Required for Mobile System Design

A commercially viable system must efficiently utilize the available resources while providing the user with an acceptable grade of service. Highest possible system capacity is critical to exploiting the economies of mass markets, and consequently to reducing user cost. Also, a careful balance has to exist between the design, capabilities, and cost of the different system segments, namely, user terminals, spacecraft, and fixed ground station(s). In general, more robustness means higher cost, either through the allocation of extra resources or added system or subsystem complexity.

To enable the careful design required, as much as possible detailed knowledge about the physical channel is required. This is particularly true for the AMT which operates in a challenging propagation environment that can have a very significant impact on terminal performance, terminal design and implementation cost. This propagation environment is central to the determination of link requirements, link operation and protocols, and ultimately, system capacity and overall viability.

The two most obvious propagation effects in the Ka-band mobile channel are shadowing and rain attenuation. Shadowing is handled in the AMT at different levels, in the pilot tracking/acquisition circuits, in the antenna controller, and in the modem and speech coder. The pilot tracking and antenna pointing schemes have to withstand a certain degree of signal drop-out due to shadowing. Frequent loss of tracking and/or switching to an acquisition mode is disruptive to terminal operation. The duration and depth of the typical shadowing events are extremely important for the proper design of these subsystems. Shadowing is also handled through the design of a modem that can "freewheel," i.e., not lose symbol synchronization through a deep fade and reproduce valid data soon thereafter. The statistics of fade length and the nature of the onset and recovery of shadowing episodes for a variety of road types are important parameters required for proper modem design. Short duration statistics of light fading are also useful in the design of the speech codec, particularly frame repetition or other schemes employed to enhance operation for brief outages. Finally, sufficient information should be available about shadowing profiles to support the design of robust communication protocols (link setup, etc.) and the rain compensation algorithm (RCA) which has to distinguish between rain and shadowing.

Very limited information is available about shadowing in the Ka-band land-mobile channel. In the design of the AMT a rough estimate of the extent of shadowing is being obtained by applying an empirical formula[1] [4] to L-band data collected with a medium gain antenna [5]. In addition models of signal outage produced by periodic sequences of utility poles are being generated. Both estimates of shadowing data will be used as testing sequences for the AMT. However, this data falls far short of the accurate, reliable statistics sought, particularly for light to moderate shadowing which is of the most interest in AMT design.

Rain attenuation is handled in the AMT primarily through data rate reduction. This is complemented with power control on the forward uplink. Due to the power limitations of the user terminal, the most critical link is that between the mobile unit and the satellite. The AMT's RCA relies on real time pilot power measurement at the mobile terminal and satellite beacon power measurement at the fixed station. Proper design of the RCA rests on the availability of rain and rain rate statistics. The probability of rain, the temporal characteristics of rain events, the impact of vehicle motion on temporal rain statistics are all required for the proper design of the RCA. Measurement averaging periods, decision criteria and regions, interaction between the RCA and the communication protocol, as well as the data rate change procedure within the communication protocol itself, are all detailed aspects of AMT design that require the applicable rain information. This information has to be for the proper range of elevation angles and locations that the AMT will operate in. The measurements and analysis being performed at VPI are a step in the direction of understanding Ka-band rain at low elevation angles. Some of the theoretical models [6,7] are also useful for the initial design of the RCA. There is, however, no substitute to experimentation using the actual mobile terminal to refine and validate any rain compensation procedures for Ka-band mobile terminals.

4. Propagation Related AMT Experiments

The emphasis during AMT experiments will be on collecting propagation data that directly impacts AMT operation, and as explained above, is necessary for optimizing system design. The channel conditions experienced in the operational locations, and hence with the pertinent elevation angles, will be observed through the actual antenna of the mobile terminal, i.e., with the proper gain and beam characteristics. A conscious effort will be made to correlate the operation of the various AMT algorithms with the observed propagation characteristics.

A typical set of AMT experiments is summarized in Table 2. The experiments combine propagation measurements with system and subsystem performance characterization. The detailed definition of the complete set of experiments will evolve in parallel with the latter phases of AMT development, namely, subsystem implementation and terminal integration and checkout.

As can be seen from Table 2, pilot signal measurements are central to all propagation related experiments. At the mobile terminal both coherent and non-coherent measurements of the pilot will be recorded. Sampling rates will be chosen to significantly exceed any possible pilot frequency variation or spreading due to Doppler or channel scatterers (such as tree tops or

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[1] This formula was derived by Weissberger [3] to predict the attenuation at various frequencies of a signal between 200 MHz to 95 GHz through groves of trees.

branches, poles, etc.).[2] The pilot tracking loop is being designed for a nominal C/N0 of 50 dB Hz, but will continue to track at lower C/N0s. Hence, in the absence of rain (98% of the time in L.A.), shadowing-induced fades of up to 30 dB could be measurable.

The data or voice channel signal will be measured by means of a power meter as well as through a received signal quality estimate obtained in the modem. Modem bit error rate performance will be measured quantitatively by using preselected PN sequences.

5. Future Experiments and Propagation Related Information

Several institutions have expressed the desire to use the AMT for land mobile experimentation. One of the possible applications would involve mounting the AMT onto a satellite news gathering truck to enable the exchange of FAX and compressed video, in addition to voice and data messages. These services would be provided between the newsroom and the truck while it is en route to the news event. The impact of the mobile Ka-band channel on these services and the AMT protocols that handle them will be evaluated.

Other experiments are being proposed to utilize much of the AMT equipment after the van and sedan tests are performed. One experiment would involve mounting the AMT on an aircraft in order to measure the Ka-band aeronautical channel. This would permit several channel characteristics to be measured, e.g., shadowing due to the aircraft body, multi-path at low aircraft-to-satellite elevation angles, and Doppler and Doppler rate. The tracking performance of electronically and mechanically steered aircraft antennas could also be ascertained. A second experiment would seek to demonstrate seamless handover of a satellite-initiated call to a cellular mobile system and vice-versa. Operation of such a hybrid satellite/terrestrial system would be tested and the effects of the two distinct channels assessed. The required equipment and protocols would then be recommended.

6. References

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[4] Report 236-6, "Influence of Terrain Irregularities and Vegetation on Tropospheric Propagation," International Radio Consultative Committee (CCIR), Recommendations and Reports of the CCIR, Volume V, Propagation in Non-Ionized Media, Geneva, 1986.

[5] ALEX-1 Cumulative Distributions, Memorandum from W. J. Vogel, Electrical Engineering Research Laboratory, University of Texas at Austin, 3/23/89.

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[2] For the AMT, and mobile Ka-band terminals in general, user antenna gains of at least 20 dB are required. Multi-path scattering from the surrounding environment is therefore very limited. Scatterers would typically be objects that are at least partially in the field of view of the antenna.

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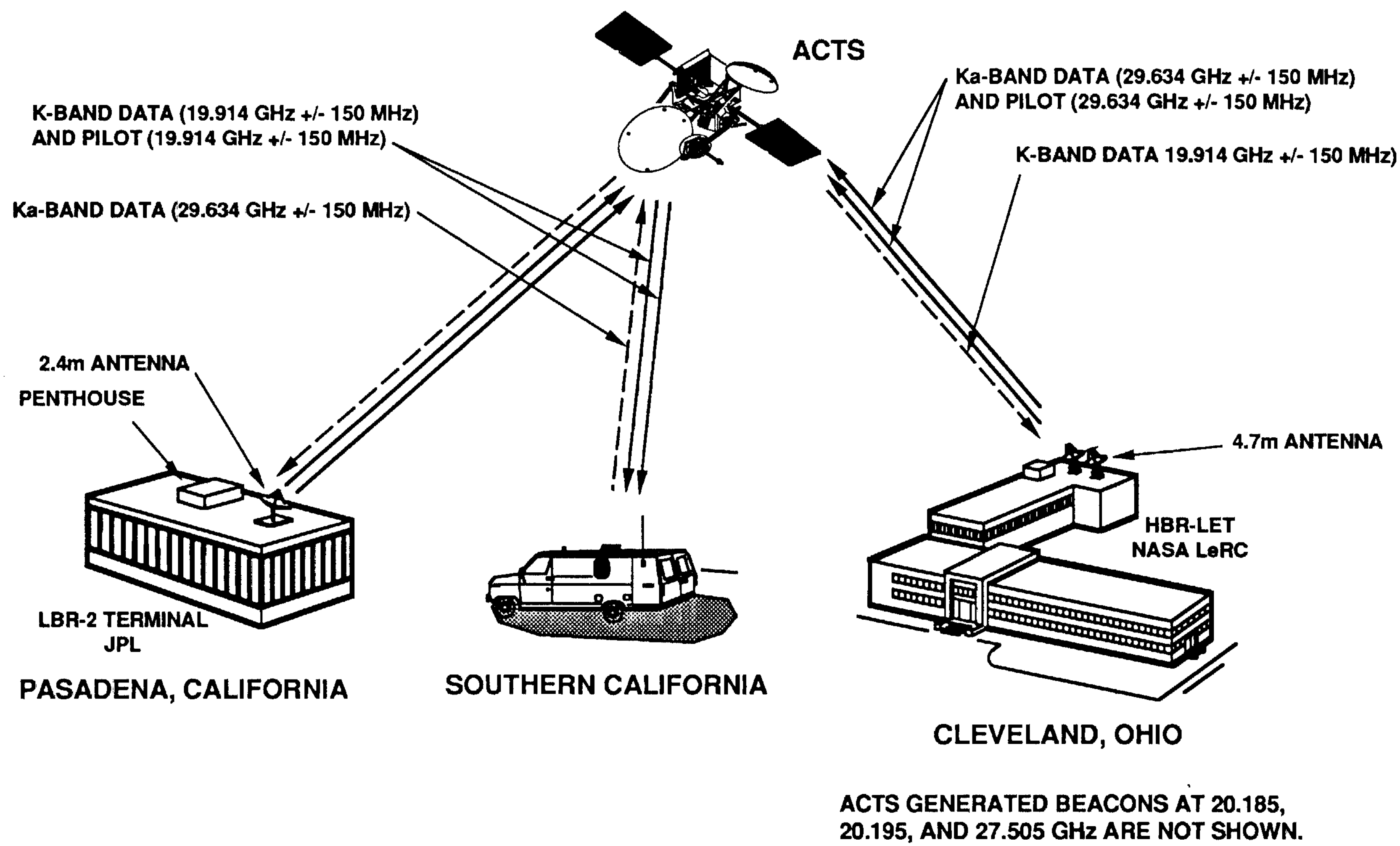

FIGURE 1. AMT Experiment Setup With ACTS

Table 1. AMT Link Budgets for Propagation-Related Experiments

FORWARD (LeRC-TO-ACTS-TO-AMT)
9.6 KBPS VOICE AND PILOT IN CLEAR WEATHER
DBPSK, CODED R=1/2, K=7, BER=1E-3
AMT AT L.A., EL=46, SUPPLIER AT CLEVELAND

UPLINK: LeRC SUPPLIER-TO-ACTS	***DATA***	***PILOT***
TRANSMITTER PARAMETERS		
EIRP, DBW	65.00	65.00
POINTING LOSS, DB	-0.39	-0.39
PATH PARAMETERS		
SPACE LOSS, DB	-213.48	-213.48
(FREQ., GHZ/MHZ	29.63	29.63
RANGE, KM)	38000.00	38000.00
ATMOSPHERIC ATTN, DB	-0.92	-0.92
RECEIVER PARAMETERS		
POLARIZATION LOSS, DB	-0.50	-0.50
G/T, DB/K	19.60	19.60
POINTING LOSS, DB	0.00	0.00
BANDWIDTH, MHZ	900.00	900.00
RECV'D C/NO, DB.HZ	97.91	97.91
TRANSPONDER SNR IN, DB	8.37	8.37
EFF. LIM. SUPPRESSION, DB *	-3.80	-3.80
HARD LIM. EFF. SNR OUT, DB	4.57	4.57
DOWNLINK ACTS-TO-AMT		
TRANSMITTER PARAMETERS		
EIRP, DBW	56.22	56.22
POINTING LOSS, DB	0.00	0.00
PATH PARAMETERS		
SPACE LOSS, DB	-209.89	-209.89
(FREQ., GHZ/MHZ	19.91	19.91
RANGE, KM)	37408.00	37408.00
ATMOSPHERIC ATTN, DB	-0.61	-0.61
RECEIVER PARAMETERS		
POLARIZATION LOSS, DB	-0.50	-0.50
RADOME LOSS, DB	-0.20	-0.20
ANT. DIRECTIVITY (MIN.), DBI	23.50	23.50
SYS. TEMP (REF TO ARRAY), K	1400.00	1400.00
G/T, DB/K	-7.96	-7.96
POINTING LOSS, DB	-0.50	-0.50
DOWNLINK C/NO, DB.HZ	65.15	65.15
OVERALL C/NO, DB.HZ	65.15	65.15
REQ'D EB/NO (AWGN--SIM.), DB	5.75	
MODEM IMPLEMENT. LOSS, DB	0.75	
REQUIRED EB/NO (TOTAL), DB	6.50	
FADE ALLOWANCE (OVERALL), DB	2.50	
DATA RATE, BPS	9600.00	
REQ'D EFFECTIVE C/NO, DB.HZ	48.82	50.00
PERFORMANCE MARGIN, DB	16.33	15.15

* CASE OF TWO EQUALLY STRONG SIGNALS IN NOISE

RETURN (AMT-TO-ACTS-TO-LeRC)
9.6 KBPS VOICE, CLEAR WEATHER
DBPSK, CODED R=1/2, K=7, BER=1E-3
SUPPLIER AT CLEVELAND, AMT AT L.A., EL=46

UPLINK: AMT-TO-ACTS	***DATA***
TRANSMITTER PARAMETERS	
EIRP, DBW	22.00
POINTING LOSS, DB	-0.50
RADOME LOSS, DB	-0.40
PATH PARAMETERS	
SPACE LOSS, DB	-213.34
(FREQ., GHZ/MHZ	29.63
RANGE, KM)	37408.00
ATMOSPHERIC ATTN, DB	-0.61
RECEIVER PARAMETERS	
POLARIZATION LOSS, DB	-0.50
G/T, DB/K	17.30
POINTING LOSS, DB	0.00
BANDWIDTH, MHZ	900.00
RECV'D C/NO, DB.HZ	52.55
TRANSPONDER SNR IN, DB	-37.00
LIM. SUP'RSS FACT. GAMMA **	0.79
DOWNLINK ACTS-TO-SUPPLIER (CLEVELAND)	
TRANSMITTER PARAMETERS	
EIRP, DBW	29.45
POINTING LOSS, DB	0.00
PATH PARAMETERS	
SPACE LOSS, DB	-210.03
(FREQ., GHZ/MHZ	19.91
RANGE, KM)	38000.00
ATMOSPHERIC ATTN, DB	-0.92
RECEIVER PARAMETERS	
POLARIZATION LOSS, DB	-0.50
ANT. DIRECTIVITY (MIN.), DBI	
SYS. TEMP (REF TO ARRAY), K	
G/T, DB/K	27.30
POINTING LOSS, DB	-0.50
DOWNLINK C/NO, DB.HZ	73.90
OVERALL C/NO, DB.HZ	51.47
REQ'D EB/NO (AWGN--SIM.), DB	5.75
MODEM IMPLEMENT. LOSS, DB	0.75
REQUIRED EB/NO (TOTAL), DB	6.50
FADE ALLOWANCE (OVERALL), DB	2.50
DATA RATE, BPS	9600.00
REQ'D EFFECTIVE C/NO, DB.HZ	48.82
PERFORMANCE MARGIN, DB	2.65

** CASE OF ONE SIGNAL IN NOISE

Table 2. Top-Level Summary of AMT Propagation-Related Experiments

TEST CONFIGURATION/CONDITIONS	TO MEASURE
I. CLEAR SKY TESTS	
1. PILOT SIGNAL STRENGTH	A. SHADOWING CHARACTERISTICS – ATTENUATION STATISTICS – DURATION STATISTICS – SIGNAL STRUCTURE FOR SPECIFIC LIGHT SHADOWING CASES
	B. ANTENNA SUBSYSTEM PERFORMANCE
2. PILOT + FORWARD DIRECTION DATA	A. PILOT AND DOPPLER TRACKING (IN AMT IF)
	B. MODEM PERFORMANCE (BER, SYNC, ETC.) – RESIDUAL DOPPLER TRACKING – FREEWHEELING THROUGH SHADOWING
3. PILOT + RETURN DIRECTION DATA	A. TWO-WAY DOPPLER CORRECTION (IN AMT IF) – L.O.S. AND SHADOWING CONDITIONS
	B. MODEM PERFORMANCE (SIMILAR TO ABOVE)
4. PILOT + VOICE	A. SPEECH CODEC PERFORMANCE – L.O.S. AND SHADOWING CONDITIONS
II. RAIN (ON ONE LINK) TESTS	
1. PILOT SIGNAL STRENGTH – CLEAR IN CLEVELAND	A. L.A. TEMPORAL RAIN CHARACTERISTICS – ATTENUATIONS AND DURATIONS AT 20 GHZ – ATTENUATION SLOPES AT 20 GHZ
– CLEAR IN L.A.-UPLINK POWER CONTROL OFF AT LeRC	B. CLEVELAND TEMPORAL RAIN CHARACTERISTICS – ATTENUATIONS AND DURATIONS AT 30 GHZ – ATTENUATION SLOPES AT 30 GHZ
2. PILOT + RETURN DIRECTION DATA – SAME AS PRECEDING	A. CORRELATION OF 20 AND 30 GHZ SIGNALS
– POWER CONTROL ON AT LeRC	B. OPERATION OF AMT COMM. PROTOCOL AND RCA
3. PILOT + FORWARD DIRECTION DATA	A. OPERATION OF AMT COMM. PROTOCOL AND RCA
4. PILOT + VOICE	A. FULL TESTING OF RCA & COMM. PROTOCOL WITH VOICE DATA RATE CHANGE ON THE FLY
	B. FULL SUBSYSTEM PERFORMANCE TESTING (MODEM, CODEC, IF PILOT TRACKING, AND TERMINAL CONTROLLER) – L.O.S. AND SHADOWING CONDITIONS

NAPEX XV

Session 2

TOPICS IN PROPAGATION STUDIES AND MEASUREMENTS

Chairman:

John Kiebler
NASA Consultant

WHAT IS HAPPENING AT CCIR STUDY GROUP 5?

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ABSTRACT--At the Plenary Meeting of the International Radio Consultative Committee (CCIR) in 1990, significant changes in the organization were adopted. These changes will affect working methods and consequently impact to some degree the technical aspects of the CCIR. Changes specific to CCIR Study Group 5 (Propagation in Non-Ionized Media) are summarized.

1. INTRODUCTION

At the XVIIth Plenary Meeting of the CCIR in Düsseldorf in May-June 1990, new working procedures were adopted (CCIR, 1990). The new format, forged somewhat in response to criticism of CCIR reliance on Reports (instead of Recommendations) and the time required to develop Recommendations, is still evolving as part of a general restructuring of the ITU. The CCIR itself has restructured into 10 Study Groups (e.g., Barclay, 1990); the main changes are the merging of Study Group (SG) 3 into SG 9 and SG 2 into SG 7, and creation of a new SG 12 on Interservice Sharing and Compatibility. SG 5 is now defining its own work areas and nature of its documentation. Changes in SG 5 technical information and its dissemination will be of concern to many users of CCIR Recommendations and Reports.

2. CCIR STUDY GROUP 5

2.1 Organization

Each SG receives study Questions from the CCIR Plenary Assembly, which the SG then assigns either to a Working Party (somewhat permanent bodies that address long-range concerns) or a Task Group (for short-term, single-topic tasks). The work of SG 5 is now divided among 3 Working Parties: WP 5A (Radiometeorology) replaces Interim Working Party (IWP) 5/3; WP 5B (Terrestrial broadcast and mobile, and mobile-satellite) assumes elements of IWP 5/1 *plus the mobile-satellite area;* and WP 5C (Fixed, fixed-satellite and broadcast-satellite) replaces IWP 5/2, *and mobile-satellite*. WPs 5A, 5B, and 5C are respectively chaired by Gert Brussaard (The Netherlands), John Cavanagh (USA), and Martin Hall (UK). At present there are no SG 5 Task Groups.

Previously, during each 4-year CCIR cycle SG 5 held Interim and Final Meetings lasting 2-3 weeks. Numerous technical input documents were discussed and acted on, and the Interim ("MOD I") and Final ("MOD F") versions of the documents were agreed.

In the new structure, essentially final versions of documents will be decided within the WP responsible for a given topic. The Interim and Final Meetings will now be brief (a few days), held mainly to either approve or reject the proposals submitted by WPs; set the SG's program of work for the next 2 years; and draft proposed new Questions or Recommendations for the CCIR Plenary. The SG is also *empowered to approve new Recommendations* provided they have been selected by the CCIR for the accelerated-approval procedure. Participation in WP deliberations appears essential to influence the technical content of CCIR Volume 5, since little if any drafting will be possible at the Interim and Final Meetings.

2.2 Organization of SG 5 Technical Information

In the past the main technical content of Vol. 5 was embodied in Reports that contained engineering advice, prediction methods, assorted measured data, and even provisional advice (perhaps "to be used with caution"). Prior to the 1990 CCIR Plenary Meeting, the CCIR's reliance on Reports (instead of Recommendations) was criticized as was also the length of time required for the CCIR to approve its Recommendations. Furthermore, the CCIR itself had recognized that providing advice that had "to be used with caution" was not likely to be useful to systems designers.

Therefore SG 5 has recently emphasized Recommendations as the primary source of information for users of its propagation information, and is in the process of transferring much of the information now in Reports to corresponding Recommendations. Data in Recommendations must be sufficiently well-developed to justify confidence in its application to systems design. Less-developed or provisional material will not transfer to the corresponding Recommendation. Reports will persist as a repository for support or developing information, mainly for internal use by the SG, and will not be formally published (but will appear in the Interim booklets). Conversely, new or revised Recommendations will be disseminated as soon as they are approved. A loose-leaf format might perhaps be selected for easy incorporation of modifications.

At a joint meeting of WPs 5A and 5C in Rio in December 1990, guidelines were adopted to promote transfer of much of the existing material in SG 5 Reports to Recommendations. Some of the ground rules that were adopted by WPs 5A and 5C for creating SG 5 Recommendations from existing Reports may be of interest, and are summarized here:

a. Recommendations should be brief, and recommend the use of the prediction methods, engineering advice, etc. in the Annex.

b. Support or provisional information or advice is to be in a supporting Report.

c. Texts are to be clear and unambiguous.

d. Repetition among Recommendations is to be minimal to avoid inconsistencies resulting from revisions.

e. Cross-references (to equations, etc.) are to be stated in both the Source and Quoting Recommendation.

f. Literature references are to be avoided in Recommendations unless they are a prime source (e.g., for a table or map); support information should be in the supporting Report.

g. Basic radio meteorology is to appear in the texts of WP 5A.

h. Basic radio engineering and service-oriented predictions, including geometry and specific algorithms in texts of WP 5C.

i. Explanatory notes that are not part of the Recommendation may be labelled and inserted in the text where required.

3. RECENT TECHNICAL ACTIVITIES

IWP 5/2, now WP 5C (Chaired by Martin Hall) and IWP 5/3, now WP 5A (then Chaired by R.K. Crane, USA) convened a joint meeting in Rio de Janeiro, Brazil, during 10-14 December 1990, mainly to address the problem of rain attenuation prediction. The impact of new tropical propagation data on the CCIR rain attenuation method is a major WP 5C assignment for the current study period (the other is interference prediction and determination of coordination distance, discussed below). The meeting immediately followed an URSI Commission F Special Open Symposium in Rio on "Regional Factors in Predicting Radiowave Attenuation due to Rain," with an emphasis on predicting rain attenuation in tropical regions of the world (J. Allnutt et al., 1991).

New data available at the Rio meeting were insufficient to generate proposals for modification to the current method for predicting rain attenuation, but 4 critical areas were identified for study:

- use of the 0.1% rain rate for prediction of attenuation in tropical regions, where the 0.01% rain rate can be extreme and difficult to measure (approach may also be beneficial for low-margin satellite communication systems);

- possible application of a vertical reduction factor to increase climate sensitivity of the existing method;

- study of the nonmonotonic behavior of path attenuation vs rain rate exhibited at high rain rates on terrestrial paths by the current prediction method;

- comparison of the slope of measured attenuation distributions with the CCIR slope (which is constant for all cases).

Based on the current availability of relevant data, the main focus in the coming period will be on the first two areas above.

WP 5C held another meeting in Abingdon, UK, during 7-14 March 1991 to focus on the problem of interference prediction and the determination of coordination distance. This meeting followed an international symposium on "Influence of the Atmosphere on Interference Between Radio Communication Systems at Frequencies Above 1 GHz," held at Leeds Castle on 5-6 March 1991, to provide the final results of the COST Project 210 (Hall, 1991).

For Report 724 ("Propagation data required for the evaluation of coordination distance in the frequency range 1-40 GHz"), WP 5C proposed that the existing procedure for calculating the Mode 1 (great-circle propagation) contours be extended up to a time percentage of 20% from the current 1%, and that the graphical methods for prediction be deleted from the Report. For Report 569 ("The evaluation of propagation factors in interference problems between stations on the surface of the Earth at frequencies above about 0.5 GHz"), which is to be converted to a Recommendation, the following proposals were offered:

- introduce the COST-210 method for duct propagation (after extension worldwide using Bean-Dutton refractivity gradient statistics), provided testing of the method is successful;

- possibly introduce COST-210 method for diffraction after testing;

- introduce the CCIR method for rain scatter interference as modified by COST-210;

The background for the new methods proposed for incorporation into the Recommendation and the background for the old methods of Report 724 is to be included in a draft Report.

The results had significant impact on CCIR Task Group 12/3 (Appendix 28) that met in Geneva during 13-22 May 1991. T. Hewitt of the UK, coordinator of the WP 5C project group on interference, chaired the Working Group on propagation at the TG 12/3 meeting.

4. TECHNICAL ISSUES FOR THE FUTURE

The near-term commitments of SG 5 concern mainly the meetings of WPs 5A, 5B and 5C that will be held in Geneva in December 1991, and the SG 5 Interim Meeting scheduled for 20-22 May 1992 in Geneva. Additional requirements are associated with the second meeting of Task Group 12/3 on possible revisions to Appendix 28 of the ITU Radio Regulations in mid-January 1992, and some input to preparations for WARC-92 (Frequency Allocations in Certain Parts of the Spectrum) that will commence in Spain in February 1992.

As to technical issues that CCIR SG 5 must address in support of the above meetings and its own program of work, the following are likely examples. In WP 5A (Radiometeorology), transfer of data on gaseous absorption and atmospheric refractive effects will be necessary. There will continue to be critical studies of the horizontal and vertical structure of rainfall, with emphasis on features in tropical climates that affect prediction methods. With continuing evolution of small-margin satellite communication systems, data will be required on propagation mechanisms for percentages of time greater than, say, 1% of the year, including clear-air effects and rain rate statistics.

WP 5B will address the areas of propagation over the Earth's surface, including the electrical characteristics; diffraction; and propagation over irregular terrain, with a particular emphasis on the application of digital terrain databases. With its new responsibilities in the increasingly important area of mobile-satellite systems, a program to attack related technical issues will be needed. As mobile-satellite systems will now be removed somewhat from deliberations on the other slant-path topics, a mechanism for coordination between WPs 5B and 5C to ensure that technical data are exchanged will be required.

In WP 5C, a traditional domain of user Recommendations and Reports, as indicated above attention must be concentrated in the near future on regional (mainly tropical) aspects of rain attenuation prediction, and prediction of intersystem interference and evaluation of coordination distance. Continuing developments in small-margin communication systems will stimulate interest in propagation impairments for higher time percentages and dynamic features of propagation events (especially for application to adaptive impairment mitigation techniques). For the fixed services, work will continue on propagation distortion, diversity, a variety of clear-air effects, and fading distributions.

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