OVERALL SYSTEM ADMINISTRATION—TERMS AND CONCEPTS

MICROWAVE RADIO

RADIO ADMINISTRATION

1. GENERAL

1.01 The primary objective of this appendix is to identify and explain significant terms and concepts that relate to microwave radio transmission quality.

1.02 Whenever this appendix is reissued, the reason for reissue will be listed in this paragraph.

1.03 The primary objective of all maintenance activity is to provide overall facility transmission performance without objectionable distortion or other related transmission impairments.

2. MAINTENANCE CONCEPTS

2.01 ***Demand Scheduled Maintenance***, as the name implies, establishes a fundamental change in preventive maintenance philosophy. This basic change is from scheduled equipment routines to performance monitoring and alignment as required. Demand Scheduled Maintenance can be defined further as performing corrective maintenance procedures when existing prescribed in-service or switch section tests indicate that equipment performance is deteriorating to the point that, if allowed to continue, service may be affected.

2.02 ***Routine Scheduled Maintenance*** is still required on certain pieces of equipment relating to the Microwave Radio System. The intervals for these tests are listed in the Equipment Test Lists and are determined from historical data on the expected deterioration time of the equipment.

3. TEST EQUIPMENT ADAPTATIONS

3.01 The ***Portable Microwave Repeater*** (PMR) has two main uses. It enables keeping the protection channel available in the event of a radio channel failure when a radio bay is out of service. Benefits in reliability vary according to the following criteria:

(a) Length of switching section, (ie, number of radio hops)

(b) Number of regular and protection channels in the switching section, (ie, protection channel to regular channel ratio)

(c) Type of equipment being protected with the PMR, (ie, tube type equipment or solid state equipment).

3.02 Substituting the PMR for the normal working bay or protection radio bay permits continued operation with a protection channel still available. The change in protection channel ratios required by the FCC expanded the need for the PMR in order to maintain reliability of Microwave Systems by making the protection channel available during maintenance activities. At present, the portable microwave repeaters are applicable only to the 4-GHz radio system. As a testing device, the PMR can be used instead of a regular working bay during trouble isolation within a switch section.

CAUTION: Portable microwave repeaters may not be useful for the isolation of marginal noise or baseband problems.

3.03 As in all maintenance activity, manual switching of channels or equipment should be kept to a minimum as all switching can cause hits on data and television services. Use of the PMR should be governed by local company policy and good judgement.

3.04 ***Radio Performance Analyzer (RPA).*** The Scientific Atlanta Model 4680 and 4683 RPA provide a fast and accurate method of measuring and recording baseband response, noise load and thermal noise, and tone search. The RPA provides maintenance personnel the means to perform quick measurements of the switch section and recognize gradual degradation of transmission parameters before they adversely affect the system.

4. TRANSMISSION IMPAIRMENTS

4.01 Factors relating to microwave transmission must be understood in order to effectively maintain transmission quality. The following explanations of transmission impairments are intended only as an overview.

4.02 ***Baseband response:*** The baseband response characteristic of a radio system can be expected to exhibit one of three general shapes.

(a) The preferred shape: flat from 1-MHz through 9.5-MHz.

(b) The rolled-up condition: starting about midband and extending through 9.5-MHz.

(c) The least desirable shape is the rolled-off condition starting at about midband and extending through 9.5-MHz.

4.03 The baseband response of each radio channel should be as flat as possible. If it is not, service over the channel may be adversely affected. The effect on transmission performance depends on the accumulated amount and character of the nonflatness.

4.04 In the case of television service, excessive baseband response distortion (in the low frequency region below approximately 500-KHz) causes smearing or streaking in the picture. Excessive high frequency roll-off (1- to 4-MHz) causes loss of picture resolution. Although the receiving Television Operating Center (TOC) has a variable equalizer to provide final adjustment of the high frequencies relative to the low frequencies, this equalizer has a limited range; furthermore, it is not effective below approximately 2-MHz. Therefore, the receiving TOC cannot compensate for excessive color subcarrier level difference nor can it compensate for response impairments below 2-MHz.

4.05 The baseband response characteristic of radio channels carrying television service becomes even more critical for those cases where the audio is diplexed with an audio subcarrier at 5.8- or 6.4-MHz.

4.06 For telephone service, baseband response roll-off conditions between 64-KHz and approximately 8-MHz affect individual supergroups differently, with the result that an excessive number of adjustments of a supergroup level may be required. From an individual message circuit point of view, any roll-off characteristic of the baseband response affects the signal-to-noise (S/N) ratio of a specific message circuit. Decreasing the S/N ratio of individual message circuits in the upper region of the baseband spectrum will result in those circuits exhibiting a higher than normal noise characteristic. Isolation and correction of the decreased S/N ratio characteristic is often difficult to isolate since baseband roll-off and S/N ratio characteristics are cumulative. It is possible for message circuits that are made up of multiradio switch sections to exhibit serious S/N ratio problems between message terminals and at the same time each switch section involved to be within limits.

4.07 ***Noise load:*** One of the most significant factors in radio system design is noise performance. With the increased circuit loading of Microwave Radio Systems, it is now increasingly important to meet switch section noise requirements. The noise load curve is divided into three regions:

(1) Thermally controlled region (thermal noise exceeds the cross-modulation noise)

(2) Cross-modulation controlled region (cross-modulation noise exceeds thermal noise)

(3) Zero (normal) drive region (thermal noise and cross-modulation contribute equally to total noise).

4.08 Some of the major causes of irregular noise load results are:

- Gross Radio Problems
- Low B0 Level
- Defective Amplifiers
- Low Receive Level

- Channel in Fade Condition.

4.09 ***Noise sources:*** There are two basic types of noise within a Microwave Radio System:

- Thermal noise (idle noise)
- Cross-modulation (intermodulation).

4.10 ***Thermal noise***, which is always present despite the absence of modulation, consists of noise generated mainly in the down converter and low level preamplifier stages of the receiver. Also, noise from microwave generator sources can influence the thermal noise "floor" of a Microwave Radio System. Thermal noise (also called fluctuation noise) is the random noise power of a radio channel when the carrier is unmodulated. It is the power summation of noise generated by:

(a) The transmitting equipment at the head end of the radio channel.

(b) The intermediate radio repeaters.

(c) The receiving equipment at the near end of the radio channel.

(d) Interferences due to other channels in the system or nearby systems.

4.11 In the absence of specific noise problems, the amount of thermal noise depends primarily upon the length and makeup of the radio facilities. Assuming equally received carrier powers at all stations, the thermal noise contributed by the radio repeaters increase 3-dB each time the channel length is doubled. (This noise is completely random in character and adds on a 10 log or power basis.) The noise due to interference normally should have only a small effect on the overall thermal noise.

4.12 ***Cross-modulation (intermodulation) noise*** is introduced into the system through nonlinearities in the equipment and/or lack of proper envelope delay equalization. Intermodulation noise does not change linearly with frequency modulation deviation as does thermal noise. It is not uncommon in highly nonlinear radio systems for the intermodulation products to change 6- to 8-dB with 1-dB change in drive level. Whenever a radio system is suspected of out-of-limit intermodulation noise, the envelope delay distortion should be measured and corrected if necessary. A serious nonlinear condition (defective transmitter amplifier or common waveguide amplifier) within the radio line may generate intermodulation products that become burned-in, thus making overall envelope delay equalization ineffective.

4.13 The following are major contributors to the overall noise performance of a microwave system.

(a) ***Channel loading:*** The more circuits per broadband channel, the greater the noise which is caused by intermodulation distortion. To decrease this intermodulation, the drive level of each circuit or per-channel deviation must be reduced. When this occurs, the thermal noise increases accordingly. Therefore, if the thermal noise can be reduced, the number of circuits can be increased without degradation of the transmission. Normal drive levels are established in order to obtain, as nearly as possible, a balance between thermal and intermodulation noise. Since thermal noise can be predicted, most radio systems' drive level is biased toward the thermal side.

(b) ***Transmission line reflections:*** Small echoes of the IF or RF signals become an important source of distortion, audible as unintelligible noise. Echoes in IF cabling and RF echoes in the antenna waveguide system are caused by slight impedance mismatches. Some typical problems causing impedance mismatch are:

- Water in waveguide
- Foreign objects in waveguide
- Corroded flanges
- Bullet holes
- Dents
- Improperly aligned waveguide flanges
- Distorted coax cables.

These mismatches cause ripple distortion characteristics which produce most of the cross-modulation noise in a system. The delay characteristics of slope and parabolic distortion can be corrected by equalization while the ripple distortion objective can be met by identifying impedence irregularities and repairing or replacing the defective equipment.

(c) ***Antenna misalignment:*** A misaimed antenna acts as a mode converter and thereby contributes to cross-modulation noise in the radio system. If antennas are aimed correctly, not only can moding be reduced, but better cross-polarization discrimination can be achieved.

(d) ***RF path reflections:*** Echoes in the RF path are produced by reflections off buildings and flat surfaces such as bare fields or bodies of water. These echoes cause nonlinear distortion which produces cross-modulation. Some of these echoes, such as those from water, can be readily located during the map study work; others are located through field checks and path testing. Repeater locations are selected to minimize echoes from these sources. Construction of buildings or ponds and the clearing of trees can increase RF path reflections. Over-the-hop fade margin tests can help identify RF path reflections.

(e) ***Repeater spacing:*** The maximum length between microwave repeaters is limited by fluctuation noise in the receiver which manifests itself as noise in the top portion of the radio spectrum. The longest possible paths consistent with good transmission performance is what a route designer attempts to obtain. The ideal length of a TD-2 radio hop is 25.5 miles. Fluctuation noise can be calculated once all parameters are known, ie, receiver noise figure, types of antennas, pre-emphasis, etc. The fluctuation noise is primarily a function of the signal strength reaching the receiver inputs. It varies inversely with the RF input to the receiver. For the nominal input level and fade margins specified by the manufacturer, fluctuation noise is kept within limits on each hop.

(f) ***RF crosstalk:*** Another source of noise which impairs voice circuits is from RF interference from other microwave signals. When designing a route, provision must be made to allow for interference within the main route and interference with the main route from converging routes and spurs. It must be pointed out that in some cases the calculated noise may exceed limits. An occasional hop exceeding the average per-hop allocation can be tolerated if other paths are sufficiently better to compensate. The real objective is to make the noise performance of each switching section equal to or less than its prorate share of the total.

4.14 ***Impulse noise:*** Impulse noise consists of short spikes of energy having an approximately flat frequency spectrum over the frequency range of interest. In the radio equipment of the affected channel, these impulses usually are generated by the following troubles:

(a) Microphonic tubes or components

(b) Intermittent conditions as a result of

(1) Dirty connections

(2) Cold solder joints

(3) Wires broken off but not separated such as broken inside the insulating cover

(4) Loose connectors

(5) Excessive switching to protection.

4.15 ***Tones:*** Spurious tones are any unwanted frequencies or group of frequencies contained in the baseband output of a receiver FM terminal. They are usually those measured at the end of a switching section of a radio route. These tones may be classified as internal and external.

(a) ***Internal tones*** are those associated with a particular radio system, its equipment or system configuration. These tones may be further identified as originating from the following:

- Microwave generators
- Microwave carrier supply tones
- Power supply tones.

Microwave generators and microwave carrier supplies may produce tones from coaxial waveguide connections that are not tight and if shields and covers are not securely in place. Poor waveguide alignment may also cause tones. Power supply tones can be caused by the converters and inverters used in various power plants. These units are switching frequencies from approximately 100-Hz to over 25-KHz. Inadequate or defective filtering on the power distribution leads or grounding can sometimes generate a sideband of tones which are harmonics of the switching frequencies.

(b) ***External tones*** are picked up by radio bay, FM terminal and/or test equipment and originate from RF radiation from nearby AM or FM broadcast stations or mobile radio transmitters. Interference from other microwave systems or from high-power radar sets may produce tones or noise in the channel under test. These tones are often beyond the control of maintenance personnel and usually require engineering assistance.

4.16 ***Cochannel interference:*** Cochannel interferences (tones) are caused when the receiving antenna picks up another radio channel operating on the same frequency. This can be caused by poor side-to-side coupling between antennas at main stations having more than two directions of transmission, and therefore, having more than one receiving radio channel operating at the same frequency. Reflections from buildings and other structures are generally the main cause of cochannel interferences being out of limits. Adjacent or parallel radio routes also can cause cochannel interference due to poor separation of these routes or, again, reflections. Cochannel interference normally does not cause problems until the regular channel fades or fails; then the initiator is unable to distinguish between the wanted and unwanted signals. Excessive noise and interference to message service may occur. It is normally beyond the resources of local operations personnel to cure excessive cochannel interference; therefore, when the interference exceeds the requirement, transmission engineering should be notified so that they can analyze the problem for possible solutions.

4.17 ***Fading:*** The propagation link is that part of the radio system least under our direct control. Propagation variations may result in increased noise levels or, in severe cases, system outage. The term fading refers to temporary deviations in the received signal level caused by variations in propagation conditions. Two of the most important characteristics of fading are fade severity and duration. Fade severity is usually classified as one of two general categories: "Deep or Shallow." Deep fades refer to signal reductions severe enough to cause complete loss of the desired signal. Shallow fades are those which result in increased channel noise and if the channel is initially operating in a degraded condition could result in loss of service or unnecessary usage of the protection channel. Fades of very short duration (usually less than a few seconds) are called "fast" fades, fades of relatively longer duration are referred to as "slow" fades. Two other pertinent properties of fading are frequency dependence and transmission direction dependence. Some types of fading affect only one radio channel at a time. These are referred to as "frequency-selective" fades. Those fades that affect all radio channels simultaneously are called "nonselective." Some types of fades affect only one direction of transmission at a time, others affect both directions simultaneously. Although fading usually is outside the control of maintenance personnel, a complete investigation and analyzation should be conducted on routes with excessive switching. Fading problems that cannot be solved by maintenance forces should be referred to engineering via lines of organization.

4.18 ***Switching systems:*** The proper operation of switching systems, THAS, TDAS, 100A, 400A, 400B, and other switching systems is extremely important as the effects of an improper operating switching system can have an adverse effect on radio transmission performance and reliability of the switch section. Both excessive switch completion and low switch completions can indicate equipment problems either in the radio equipment or switching equipment.

4.19 ***Switch register readings:*** Analysis of recorded switch register readings, if available, may identify those channels exhibiting excessive or low switch completions and determine a satisfactory ratio of the highest to lowest within a switch group. Further analysis will then indicate steps to be taken for corrective action. Excessive or low switch completions may indicate equipment or microwave path problems. When heavy demands are made on a protection channel, switching section reliability may be reduced. Excessive switches can also result in excessive errors on data circuits. Further reference can be made to Section 420-600-302.

4.20 ***Cross-polarization discrimination:*** Cross-Polarization Discrimination (XPD) expresses the ratio in dB of the power of the desired polarization to the power at the same frequency, which appears in the opposite polarization due to the residual conversion mechanism in the antenna system. The power in a cross-polarization signal is effectively converted to the operating polarization and therefore becomes a source of cross-modulation interference. The tests for XPD are made on an out-of-service basis. In most cases, assistance by radio engineers is required to correct or minimize the trouble condition.