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Engineering Note

Selective Fading in Microwave RF Repeaters

Including references to other types of fading and system reliability issues

Introduction

Selective Fading is often observed in microwave relay links. Another name is dispersive fading. The cause of this type of fading is multipath with a time delay short enough to cause signal cancellation in only part of the wideband channel hence the name selective fading. This signal cancellation causes severe signal waveform distortion. Digital Radio Equipment is especially susceptible to this distortion.

Modern Digital Radio Equipment includes several countermeasures to reduce the effect of selective fading. Countermeasures include Adaptive Equalizers and Forward Error Correction.

Microwave RF Repeaters built by Peninsula Engineering Solutions are based on high gain linear amplifiers and simply amplify a modulated microwave signal at its operating frequency to a power level adequate for re-transmission.

What are the effects of Selective Fading on microwave relay systems employing RF repeaters?

Since the RF repeater normally linearly amplifies any received signal within its filter channel bandwidth, a selective fade distorted signal will also be amplified and re-transmitted along with the waveform distortion. It is important that the amplification remain linear. When non-linearities in the repeater are combined with a distorted signal, coupled distortions such as AM/PM and Delay + AM/PM can form. Some of these distortions cannot be corrected at the terminal receiver.

Because of this concern about linearity, the RF Repeaters from Peninsula Engineering Solutions incorporate Automatic Gain Control that compensates for path fading caused level change and controls the power output level. This control or AGC is designed to keep the microwave signal within the linear operating range. Specific power levels are set for each type of modulation encountered.

One consideration is that the AGC circuit regulates the power level by detecting the total power in the filter channel bandwidth. This can lead to shifts in the regulation point during dispersive fades where the channel energy distribution is altered. The figures below illustrate this effect.

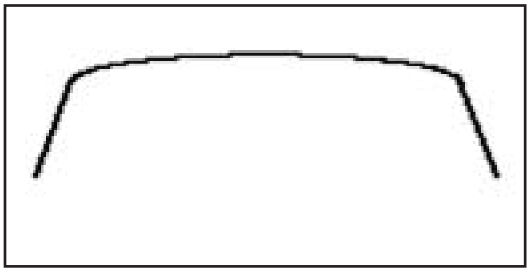

Figure 1 Normal Signal Spectrum

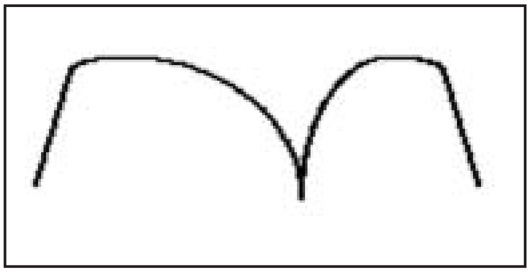

Figure 2 Distorted Signal Spectrum In-band Notch

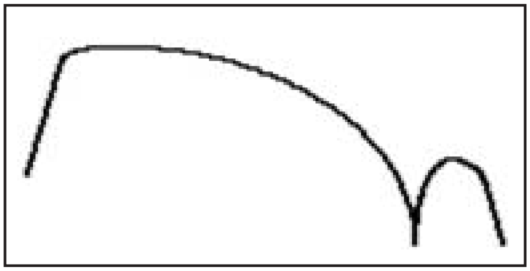

Figure 3 Distorted Signal Spectrum Edge Notch

When the signal is distorted, the AGC will try to maintain the set level regulation. The AGC RF level detector is a semi-peak responding type rather that an average responding detector. This sensitivity to peak energy is important to note since non-linear distortion in digital radio signals is mostly peak power dependent. The AGC circuit will then maintain the peak power within proper limits.

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Additional Considerations

Three additional considerations in the RF repeater design that improve the response to selective fades are:

1) AGC *time constant* is relatively long in order not to interfere with the RMAS telemetry. This long or slow response maintains the gain setting close to the unfaded condition during very fast dispersive fades. This lessens any significant level shift.
2) There are several dB of power margin built into the RF repeaters. When a shift in level does occur it is typically 1 ~ 3dB only and that will result in only minor performance degradation.
3) The AGC has a nominal 5dB reserve for up-fades or when the multipath is in-phase and the signal levels increase. Thus, protection is extended to both up and down fades.

Assumptions on RF Repeater path fade outage calculations

Each hop of the repeater is considered to fade independently. AT&T and Bellcore practices indicate that on multihop systems, each hop is calculated independently and the outage probabilities summed for the total section. This is considering fading due to multipath only - *Dispersive Fading or Selective Fading.*

Multipath fading is characterized by very sharp two and three ray signal phase cancellations, which are very brief in time. The standard assumption for fast fade rate is 100dB per second, which can occur over the last 10 dB of a 40 dB deep fade. This is the slope of the fade attenuation change over time.

Obstruction fading can also occur on paths without enough clearance. When the atmospheric refractive index changes (k factor) and causes the radio beam to be lowered, then high points on the path or the curve of the earth itself can appear to rise and block the signal beam causing attenuation and fading. Obstruction fading is not considered much anymore as most radio engineers have the necessary design tools and knowledge to lay out a radio path good enough to avoid obstruction fading.

Rain fading occurs at frequencies above 9 GHz on path lengths normally associated with terrestrial point-to-point microwave links. Heavy rain from thunderstorms can attenuate the signals enough to cause an outage. Light to moderate rain has little effect. RF repeater models for rain outage calculate each hop independently again. This might not always be true of one considers that a large thunderstorm might cover two short or connected hops. This is not possible to predict today and so we don't consider it. RF repeaters are more limited in maximum system gain than terminal radios (60dB vs. 90 to 110dB) and are not so independent hop-to-hop.

During rain fades, the thunderstorm's strong air currents mix up the air so much that conditions cannot cause multipath fading. Therefore rain and multipath fading are considered to be independent. Outage due to rain is simply added to outage due to multipath.

Rain, unlike multipath, affects both directions of transmission on one hop. Rain outage time is considered two-way outage and is not summed for both directions, as is multipath.

Calculations

To calculate the outage time per hop, the fading probability is first determined. As above, this is done hop by hop. In the case of one RF repeater, two hop link, the input hop and output hop have different considerations. See Figure 4.

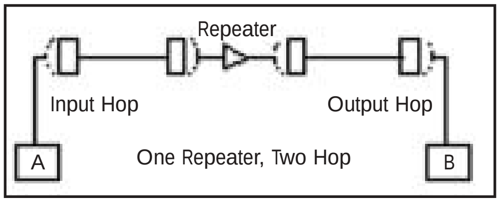

Figure 4, Reference Link

Start with the output hop. The input hop is considered to be in normal unfaded conditions with normal receive level. The repeater output power is then as calculated by the path data sheet. The repeater to terminal B across the output hop is then considered to be the same as a normal terminal to terminal hop. The terminal has a threshold signal level (lowest signal for given performance, 10-6, 10-3 BER). The normal terminal B signal level is determined from the path calculations. The difference between normal and threshold is the output hop fade margin.

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Fading probability is calculated knowing this fade margin, frequency, hop length, terrain roughness, climate, and mean temperature plus improvements due to frequency diversity and space diversity.

The input hop is again calculated as an independent outage. The RF repeater's minimum receive signal level is dependent on the terminal B threshold, noise figure, output hop net path loss and repeater gain. The repeater minimum receive level is determined to be the low level that causes the repeater output power to drop (at maximum repeater gain) and thus cause the receive level at terminal B to drop to the point above terminal B's rated threshold where the combined noise from the terminal B and repeater set the terminal C/N = the C/N at rated terminal threshold. The link from repeater to terminal B is considered to be at threshold performance. The minimum repeater receive signal at the repeater causes the following terminal (B) to operate at minimum rated performance.

The repeater minimum signal level is calculated by the cascaded noise figure method adjusted for all the loss and gain elements in the hop. These calculations are included in Peninsula Engineering Solutions *Microwave Path Data Sheets.*

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Reference literature on radio and microwave fading:

Title	Author	Agency	Doc number
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RMAS-120 Remote Monitor and Alarm System – Operations Manual	Engineering, September 1997	Peninsula Engineering Solutions	550-0782-01

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