The Impact of Seasonal Foliage Changes on Clutter Modeling

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***Abstract*—Development of improved clutter modeling is critical to co-existence of incumbent and entrant systems. Most clutter modeling approaches center on a median clutter loss term and a statistical distribution representing location variability. In this paper we show that an overlooked component of clutter model development is time variability. Through measurements at two transmitter sites and at two frequencies, we provide data showing how changes in foliage during the year can have a significant impact on clutter loss, in particular at higher elevation angle path geometries.**

I. Introduction

Spectrum sharing requires detailed sharing and interference studies to ensure co-existence between incumbent and entrant systems. At mid-band frequencies, most entrant systems are commercial cellular systems. When user equipments (UEs) are the source of interference to incumbent systems, statistical clutter models provide a method to perform complex sharing and interference studies as they are well-suited for large-scale analyses such as Monte-Carlo simulations.

In such simulations, the analysis area can be gridded with pre-computed median clutter loss values. UE's can then be deployed within the simulation (either randomly or based on agreed-upon deployment scenarios). Each UE's total clutter loss is then determined by selecting from the statistical distribution component of the clutter model representing location variability within the environment.

Many statistical clutter models [1]–[3] have been developed in this way to support sharing studies. While they differ in how they define the clutter environment and treat terrain effects, they all treat clutter loss by combining a median loss value with a statistical distribution representing location variability.

An overlooked statistical component of these clutter models is time variability, which models changes in expected basic transmission loss over the course of a year. Time variability traditionally captures the impact on the propagation channel of meteorological effects due to changes in the atmosphere over time. These statistical effects are present in some general purpose models such as [4], [5].

This paper investigates the time variability of clutter loss due to seasonal foliage changes. The impact of seasonal changes in vegetative attenuation has been studied and presented in [6], albeit by treating vegetative effects independent of the rest of the environment. This paper considers vegetative effects as part of a suburban clutter environment. We performed two sets of clutter measurements; one in winter and one in summer. We present the results as a form of clutter loss time variability and discuss its implications for the development of future clutter models.

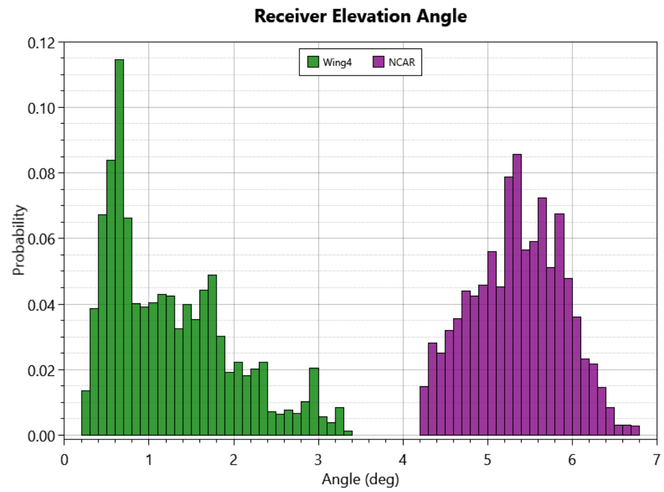

Fig. 1. Distribution of elevation angles for each transmitter location.

II. Measurements

To measure the impact of seasonal changes in foliage on mid-band clutter, mobile clutter measurements were performed in the Martin Acres suburb of Boulder, CO, east of the Department of Commerce (DoC) Lab. The neighborhood contains single family homes with a mix of large mature deciduous and evergreen trees through-out.

To provide a diversity of both elevation angles and bearings, two transmitter locations were selected: on the roof of Wing 4 of Building 1, DoC Lab, and a cell-on-wheels (COW) at the National Center for Atmospheric Research (NCAR) parking lot. Path distances ranged from approximately 0.5 to 3 km. The distribution of elevation angles along the drive route for each transmitter is shown in Fig. 1.

Two frequencies were chosen at 3175 MHz and 3475 MHz to avoid existing systems in the area. A vehicle acting as the receiver drove a predefined drive route through Martin Acres. The two transmitters simultaneously transmitted a continuous wave (CW) signal with an omnidirectional antenna, at 3 kHz offset around the nominal frequency. The two simultaneous CW signals were captured by the mobile receiver and recorded. The individual transmitted signals were later extracted through digital filtering and post-processed to remove the effects of fast-fading, as described in [7].

To capture seasonal variation, the measurement was performed twice, on December 16, 2022 (winter) and again on June 21, 2023 (summer). During the winter measurements, trees and vegetation were free from all precipitation.

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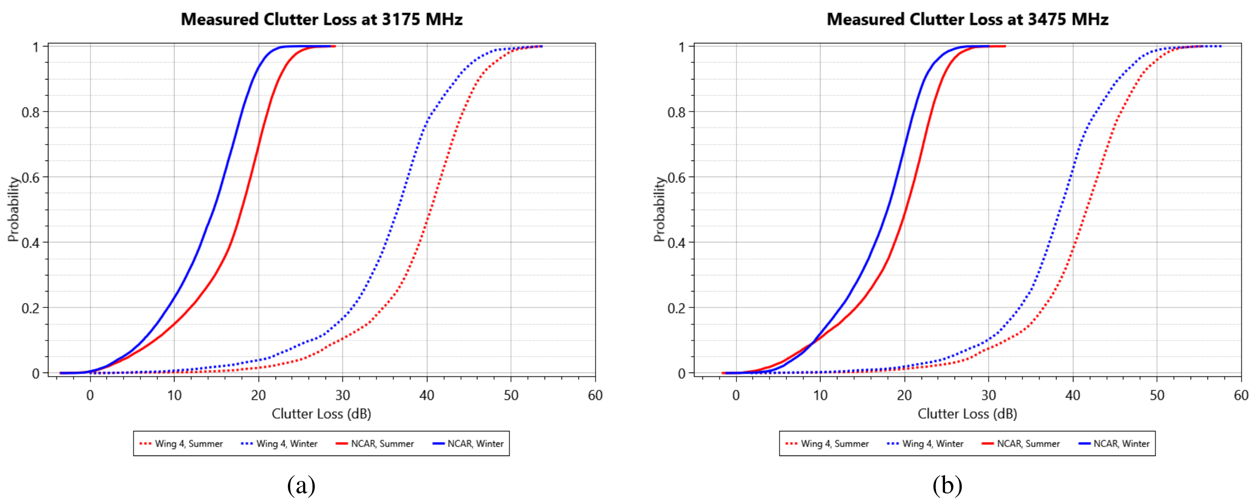

Fig. 2. Measured clutter loss statistics for (a) 3175 MHz, and (b) 3475 MHz organized by transmitter location and season.

III. Measurement Results

The measurement was designed to avoid terrain interactions, so that loss in excess of free space would represent clutter loss. Fig. 2 shows clutter loss measurement results, organized by frequency, transmitter location, and season. Table I presents summary statistics of the clutter loss measurements. As expected, losses were greater in the summer during full foliage than during winter when deciduous trees were void of leaves.

Table II focuses on the differences between summer and winter; positive values indicate greater losses during the summer. Transmissions from the Wing 4 transmitter were more affected by the presence of foliage than those from the NCAR transmitter, possibly showing an elevation angle dependence. For both transmitter locations, the change (Δ) of seasonal foliage was also greater at 3175 MHz than at 3475 MHz.

While the median value of clutter loss was impacted by foliage, the standard deviations were independent of it. For both transmitter locations and both frequencies, minimal change in standard deviation was observed. Of particular note is that while the magnitude of the impact on median loss appears small (around 2-3 dB for this neighborhood), it disproportionately affects higher elevation angle paths. For the NCAR transmitter, with elevation angles up to almost 7 degrees, a change of 2-3 dB results in approximately 10 to 20% change in total clutter loss. This can be significant for analyses involving elevation or aeronautical systems.

TABLE I
Measured clutter loss statistics.

Freq (MHz)	TX	Summer Median (dB)	Summer Std Dev (dB)	Winter Median (dB)	Winter Std Dev (dB)
3175	Wing 4	39.16	6.80	35.45	7.23
	NCAR	16.49	5.70	13.66	5.02
3475	Wing 4	40.65	6.62	37.79	6.66
	NCAR	18.63	5.72	16.87	5.00

IV. Conclusion

This paper presents the results of a measurement experiment looking at the impact of seasonal foliage changes on clutter loss, presenting clutter loss statistics for a suburban environment containing mature trees. These results motivate deeper consideration toward the future incorporation of time variability distribution into statistical clutter models, in particular for elevation path geometries where seasonal variation of clutter loss due to foliage can constitute a substantial fraction of total clutter loss.

References

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TABLE II
Seasonal differences in measured clutter loss distributions. Positive values indicate larger losses in summer.

	3175 MHz Δ Median	3175 MHz Δ Std Dev	3475 MHz Δ Median	3475 MHz Δ Std Dev
Wing 4	3.71	-0.43	2.86	-0.04
NCAR	2.83	0.68	1.76	0.72

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