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Anita Longley's Legacy: The Longley-Rice Model – Still Going Strong After Almost 50 Years

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1. Introduction

At the dawn of the computer age, Anita Longley, Phil Rice, and their colleagues at the Central Radio Propagation Laboratory (CRPL) (now the Institute for Telecommunication Sciences (ITS)) realized that the computational capabilities of the new machines could result in vast improvements of the modeling – and design – of radio systems used by the military and the public in a wide array of applications. The necessity for propagation modeling became evident during World War II, as it was vital for pilots to have reliable communications systems.[1] In the late 1960s, when the Longley-Rice model was developed, land mobile radio and television systems required better engineering than had been available up to that point in time [1]. Marrying an empirical model (based on electromagnetic theory) with measured data (terrain features and radio measurements) provided that better engineering, and resulted in algorithms still in wide use today.

The Longley-Rice Model predicts tropospheric radio transmission loss over irregular terrain for a radio link (from transmitter to receiver), and is referred to as the Irregular Terrain Model (ITM). The model was designed for frequencies between 20 MHz and 20 GHz, and for path lengths between 1 km and 2000 km [2]. The model has two prediction modes: point-to-point (which requires the terrain profile between the transmitter and receiver), and area prediction (which estimates the impact of terrain by empirical and statistical methods). The result of the model is the median attenuation of a radio signal as a function of distance, and the variability of the signal in time and in space [3].

The model was designed to provide a means by which terrain roughness could be factored into the determination of signal strength [4]. The quantitative estimates of propagation characteristics help to determine how well proposed radio systems will meet requirements for satisfactory service, free from harmful interference. At the time of the model's development, this was and today remains an important step toward more-efficient use of the radio-frequency spectrum [5].

Currently, the United States Federal Communications Commission (FCC) provides guidance on the implementation and use of the methodology for evaluating television service coverage and interference [6]. The FCC allocates commercial

[1] When the Central Radio Propagation Laboratory was created in 1946, its mission was to provide radiowave propagation research and services, radio standards, and studies on the efficient use of the spectrum for all US government agencies.

and non-federal spectrum. In the US, the National Telecommunications and Information Administration (ITS is its research arm) allocates federal spectrum to the military and non-military government agencies. These allocations rely on computer models that incorporate the rapidly evolving technology developments of the last fifty years. Many of the more-sophisticated computer models in the 21st century that take advantage of satellite data and advanced programming languages for determination of radio transmission loss have the basic Longley-Rice methodology embedded in their programming [7].

2. Radio Propagation Issues

Comprehensive and accurate calculation methods for transmission-loss data were realized to be necessary by reviewing the long-term median values of attenuation when graphed as a function of the length of the path between the transmitter and receiver. The significantly wide diversity of those values reflected differences in terrain profiles and antenna heights. The range of differences at times exceeded 100 dB (see Figure 1). In order to minimize interference between co-channel and adjacent-channel systems, more-accurate predictive methods were viewed as being highly beneficial [5].

3. Empirical Model Compared to Actual Data

Longley, Rice, and their colleagues at the CRPL set about to develop more-accurate predictive methods. Their model incorporated a wide variety of different climates, terrain, and ground conditions. Climates included equatorial, continental subtropical, maritime subtropical, desert, continental temperate, maritime temperate over land, and maritime temperate over sea. Terrain type selections included water or very smooth terrain, smooth terrain, slightly rolling terrain, hilly terrain, and rugged mountains. Electrical ground constants and soil-conductivity choices included average ground, poor ground, good ground, fresh water, and sea water [3, 5, 8].

To validate their empirical model, Longley and others compared transmission-loss data from nearly 800 paths from various parts of the world to the values predicted from the Longley-Rice model. Much of these transmission loss data had been gathered during World War II. In fact, collection of radio transmission-loss data had begun in 1909, under the Radio Section (a predecessor to the CRPL) of the National Bureau of Standards (now the National Institute of Standards and Technology (NIST)). The measurements were made at frequencies from 40 MHz to 10 GHz over distances that ranged from 10 km

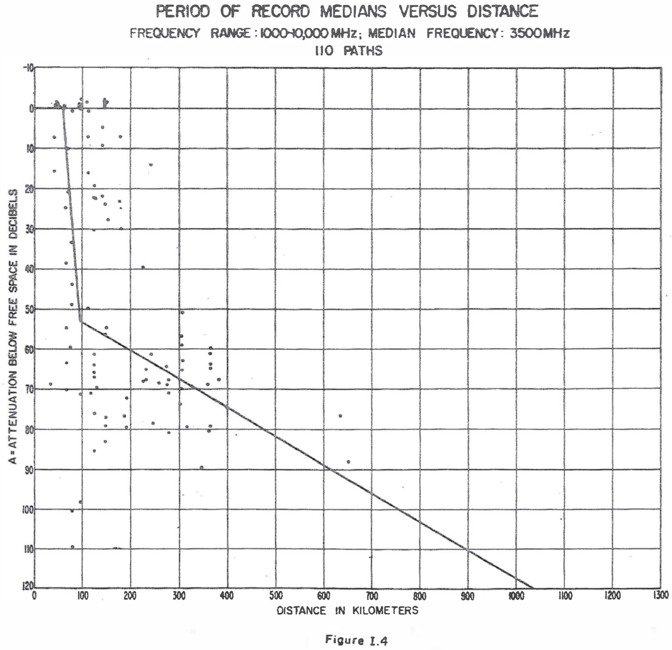

Figure 1. A reproduction of Figure I-4, Technical Note 101, page I-7 [5].

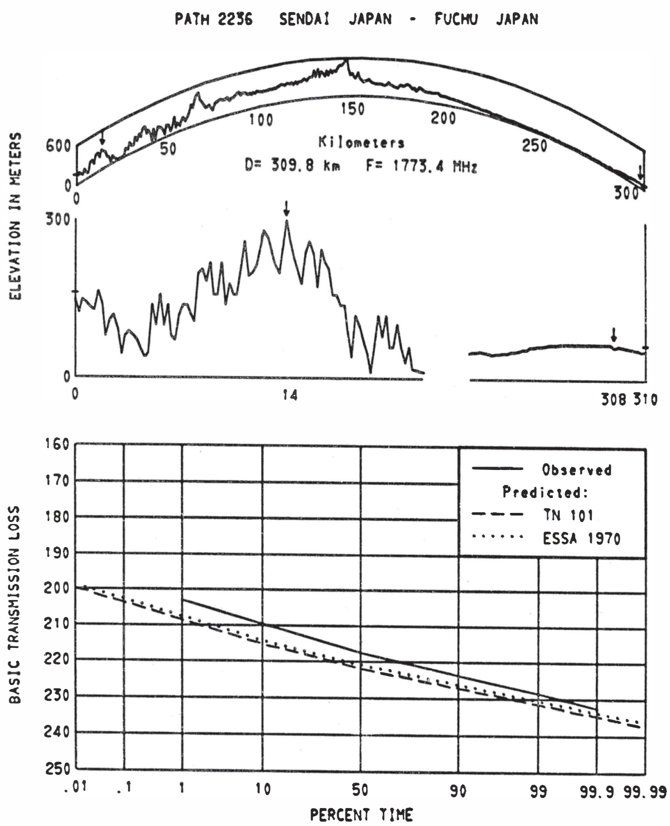

Figure 2. A reproduction of Figure 3.184, path 2236[3] [9].

to 1,000 km. Their efforts included plotting terrain profiles and cumulative distributions for more than 500 of the paths. Different climatic conditions were evaluated, and different assumptions were made for different areas of the world [9].

With some exceptions, there was good agreement between measured data and the values predicted by the Longley-Rice methodology, especially where forward scatter was the dominant mechanism (see Figure 2). The data represented line-of-sight, diffraction, and forward-scatter propagation mechanisms, as well as the effects of super-refraction and ducting, as available [9].

4. Applications

The original use of the Longley-Rice methodology was in frequency planning in television broadcasting in the US in the 1960s, for military applications, and for non-military government use [2]. Results of the models were used to prepare the tables of channel allocations for VHF/UHF broadcasting. With accurate estimations of transmission-loss attenuation, reliable mobile-telephone systems could be designed, radio navigation and conditions for international shortwave broadcasters could be improved, as could the operation of radar systems. Marine communications and air traffic control and air navigation systems needed accurate loss estimations, as well. Another interesting and important non-military government application included satellite systems for weather forecasting by the National Oceanic and Atmospheric Administration.

5. Anita Longley

Anita Longley (Figure 3) was born in the province of Saskatchewan, Canada, and received her BA in Physics from McMaster University. She received her MS in Physiological Chemistry from the University of Minnesota. After serving as a research assistant and teaching at the high school and university levels, she joined the National Bureau of Standards (NBS) CRPL in Boulder, Colorado, in 1955.

Her main research focus was the development and testing of tropospheric propagation models. These models have applications to communication over irregular terrain, and she further examined the effects of climate on long-term variability.

She was a member of the US Study Group V for the International Radio Consultative Committee (Comité Consultatif International des Radio Communications – CCIR). She was also a member of the IEEE, the Scientific Research Society of America (RESA), and Sigma Xi. She was awarded the US Department of Commerce Silver Medal for joint authorship of NBS Technical Note 101 on "Transmission Loss Predictions for Tropospheric Communication Circuits," which is still widely referenced today.

Figure 3. Anita Longley (courtesy of NTIA).

At a time when women engineers and computer scientists in the US were very rare[2], Longley wrote or collaborated on more than 20 research reports. With P. L. Rice, she prepared many of the reports that were included in the published documents of the CCIR (Documents of the XIth Plenary Assembly, Oslo, 1966). She presented a talk at the conference sponsored by the Advisory Group for Atmospheric Research and Development (AGARD) of the North Atlantic Treaty Organization held in Dusseldorf, Germany. She presented papers at meetings of the International Union of Radio Science (Union Radio-Scientifique Internationale – URSI), lectures for local short-term propagation courses (including five lectures for the "Tropospheric Radio Propagation Course," 1970), and numerous reports to sponsoring agencies, including the US Air Force Space and Missile Systems Organization (SAMSO), the United States Army Electronic Proving Ground (USAEPG), and the US Army Security Assistance Management Directorate (SAMD) [11, 12].

6. Conclusion

Anita Longley, Phil Rice, and their colleagues at the Central Radio Propagation Laboratory provided a legacy still in use today, almost 50 years after its development. Few outside of the world of radio propagation understand the breadth and utilitarian value of the Longley-Rice model in enabling the myriad of communications applications we enjoy and rely on for our safety and security every day.

[2]The first year that the percentage of women receiving BS degrees in engineering in the US reached 1% was 1972 [10].

7. Acknowledgment

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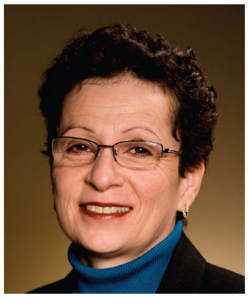
Introducing the Author



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