The Smith chart

For half a century, this famous graphical aid has literally run rings around the problems of transmission line analysis

Phillip H. Smith, an engineer at Bell Telephone Laboratories, radically simplified transmission line analysis by developing the graphical aid named after him. He introduced his chart in the 1930s, in time for an enhanced version to prove invaluable to the designers of microwave devices and systems during World War II, and it flourishes to this day, despite being a survivor from an analog age in a digital era.

When Smith invented his chart, analog methods of calculation were everywhere, in the form of slide rules, nomographs, and graphical characteristics of vacuum tubes and electrical machinery. Outliving all the rest, his became perhaps the most distinctive graph in electrical engineering [see illustration] and is still marketed in a variety of forms by the company he founded, Analog Instruments Co.

Smith was born on April 29, 1905, in Lexington, Mass., and majored in electrical engineering at Tufts College in nearby Medford. His alma mater was known for its emphasis on graphic language and especially for the course in engineering graphics taught by Gardner Anthony. Smith graduated from Tufts in 1928 and joined Bell Telephone Laboratories, where he remained until his retirement in 1970.

In 1929 the young engineer was assigned to a short-wave radio transmitting station operated by the Bell Co. in Lawrenceville, N.J. This station employed numerous directive antennas and provided radiotelephone service to both Europe and South America. It was at Lawrenceville that Smith developed his first graphical aid, for matching antennas to transmission lines. He used a rectangular form of a graphical chart based on a transmission line equation credited to the British physicist, John A. Fleming.

Following his transfer, in 1934, to the Radio Development Department at Whippany, N.J., Smith designed phasing and coupling apparatus for a number of commercial broadcasting stations. Meanwhile, he went on improving his transmission line graphs and by 1936 had developed a polar coordinate form on which all values of line impedance could be shown.

Two colleagues showed him how to use a conformal mapping technique to produce a chart with orthogonal circles that were easier to draw than the polar chart. In the conformal mapping chart, the user plots curves of constant standing wave ratio as circles concentric with the chart's center.

Smith disclosed the transmission line calculator in the January 1939 issue of *Electronics*. The paper included a full-page illustration of the chart with a radial arm to be pivoted at the chart center, and described it as suitable for readers to cut out and use as a home-made calculator. Smith published a follow-up article on the chart used as a calculator with improved accuracy in *Electronics* in January 1944. He noted that the war, by then under way, had stimulated interest in the calculator among engineers working in the ultrahigh-frequency field. Researchers working at the Radiation Laboratory at the Massachusetts Institute of Technology in Cambridge were finding that the Smith chart was extremely useful in designing microwave radar systems.

During the war years, Smith himself worked on antennas for the SCR 268, an early radar, and also on microwave radar antennas. After the fighting ended, he developed the so-called cloverleaf antenna for use with frequency modulation broadcast transmitters and received a patent on it in 1950. He also contributed to the design of the antennas for the DEW (distant early warning) line, Nike radar, and SAGE (semiautomatic ground equipment) system in the postwar period.

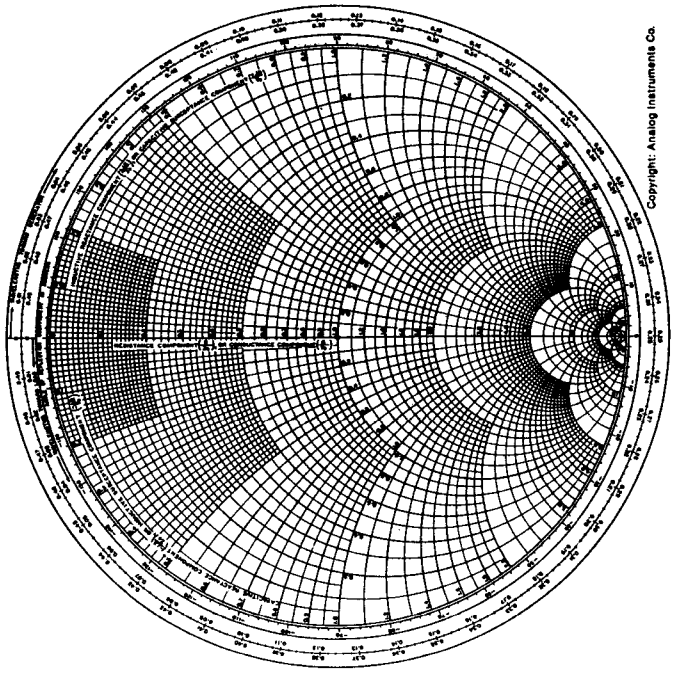
Outside his job, in 1950, Smith turned into a flying enthusiast. He came to own two small airplanes and logged more than 1500 hours in them.

In 1952, he was elected a Fellow of the Institute of Radio Engineers for his contributions to antennas and graphical analysis. In 1969, his book *Electronic Applications of the Smith Chart in Waveguide, Circuit, and Component Analysis* was published.

The next year, he retired from Bell Laboratories and founded Analog Instruments, which sold navigational instruments for the light aircraft he loved, but which later added a line of Smith charts and related items. At the time he died in August 1987, it was reported that more than nine million copies of the chart had been sold.

His wife, Anita M. Smith, has since continued the chart business. The company supplies at least 12 different types of the trademarked Smith chart, including a "negative Smith chart" for the analysis of negative resistance devices. Even modern, computer-based automatic network analyzers rely on the Smith chart for data display, and current textbooks and courses in electrical engineering still feature it.

Furthermore, since 1988 the Smith chart has been cited in papers by engineers in Canada, China, Italy, Singapore, Sweden, the United Kingdom, and the United States in connection with communications, phased arrays, noise parameter measurements, impedance matching, amplifier design, and other topics.



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