HIGH FREQUENCY
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Editorial Director
Gary Breed
gary@highfrequencyelectronics.com
Tel: 608-845-3965
Fax: 608-845-3976

Publisher
Scott Spencer
scott@highfrequencyelectronics.com
Tel: 603-472-8261
Fax: 603-471-0716

Associate Publisher
Tim Burkhard
tim@highfrequencyelectronics.com
Tel: 707-544-9977
Fax: 707-544-9375

Associate Editor
Katie Landmark
katie@highfrequencyelectronics.com
Tel: 608-845-3965
Fax: 608-845-3976

Business Office
High Frequency Electronics
7 Colby Court, Suite 7-436
Bedford, NH 03110

Editorial and Production Office
High Frequency Electronics
403 Venture Court, Unit 7
Verona, WI 53593

Also Published Online at
www.highfrequencyelectronics.com

Subscriptions
High Frequency Electronics
PO Box 10621
Bedford, NH 03110
Tel: 603-472-8261
Fax: 603-471-0716
circulation@highfrequencyelectronics.com

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There's Nothing Magic About 50 Ohms

Gary Breed
Editorial Director

Once in a while I am reminded that some seemingly important technical "standards" are nothing more than convenient, more-or-less arbitrary, choices. The deeply-entrenched 50-ohm standard impedance for RF circuits came to mind as I was reviewing and researching this month's tutorial on recent work in coaxial cables. Where did this important number come from?

The most common story is that 50-ohm high power coaxial lines were first made using standard sizes of copper pipe, such as 3/4 inch for the inner conductor and 2 inch for the outer conductor. While this may explain why certain transmission lines are 52 or 53 ohms versus 50 ohms, I don't think this is the entire story of how 50 ohms became the most common standard. Being curious, I went digging through my small collection of old reference books.

The oldest of my books, a 1928 3rd edition of *Practical Radio* by Moyer and Wostrel, has no reference to transmission lines at all. Interstage connections are made directly, which is not surprising, but antennas are all shown connected directly to the tank circuits of the final amplifier. A 1936 edition of *Electrical Engineers' Handbook* by Pender and McIlwain has a section on transmission lines, developed mainly from the paired wires of telephone technology, but also noting "concentric tube" lines, with a chart for a 50-ohm cable identified as RCA's "Cabloy" product.

The 1st edition of Terman's *Radio Engineers' Handbook* (1943) includes an extensive treatment of transmission lines, but does not make note of any "standard" line impedance. It does include information that dates to the 1920s, when it was determined that a coaxial transmission line impedance of 77 ohms provides the lowest loss, while 30 ohms provides the highest power handling for a given cable size, both assuming air dielectric and identical inner and outer conductor material.

The 1950 1st edition of Kraus' *Antennas* includes several references to the use of 50-ohm coaxial cable, but it also shows antennas for which the coaxial feedline is adapted to match the antenna impedance, as well as several antennas with "coaxial feed" noted, but no reference to a specific impedance. By 1955, Terman's 4th edition teaching text, *Electronic and Radio Engineering*, included a much more detailed section on coaxial transmission lines. This textbook's end-of-chapter problems generally use 50-ohm lines as the standard impedance.

The last text I checked was the 1st edition of Jasik's *Antenna Engineering Handbook* (1961). There is a complete reference to the "RG" series of flexible coaxial cables, as well as information on high power coax using solid tubing conductors. However, this text also includes information on 3-wire and 5-wire unbalanced lines and high power 4-wire balanced lines. At that time, these techniques were still in common use for high power broadcasting, particularly the very high powers of international shortwave and medium wave stations.

I got one more piece of information from the company history section of the Andrew Corporation Web site. In 1938, the company first made 70-ohm coaxial lines using solid copper tubing, but 50-ohm lines of the same construction were not manufactured until 1958. In the 1970s and '80s, large-size 70-ohm solid copper coaxial lines were used for the antenna feed systems at some of the new television transmitting facilities I worked on.

So, Why 50 Ohms?

The answer seems to be twofold—the convenience of adapting standard size materials for early products, plus the fact that 50 ohms is a good compromise between lowest loss and highest power handling for a given cable size. It simply caught on and managed to become the de facto standard as interconnection became common between circuit sections, not just to the antennas.

One more note is that 50 ohms caught on for RF transmission rather than the well-established 75 ohms that had been used for video transmission for many years. The "common wisdom" passed on to me during my years in broadcasting was that differentiation in function was the reason: "75 ohms is video, 50 ohms is RF." This convention apparently did not influence the engineers developing cable TV distribution, who wisely chose to use 75 ohm cable for its optimal loss performance.

Coaxial cable impedance is not the only place where standards emerged for practical, not theoretical reasons. Modulation formats, data transmission protocols, device packages and sizes, substrate materials and thicknesses—and many other things we consider standardized—are also compromises among performance, cost, usability, availability of materials and ease of manufacturing.

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