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Why 50 Ohms? The Readers Respond!

First, some background — In my June 2007 editorial, I mused about the origins of 50 ohms as a standard impedance. I tried to search as far back as possible, and determined that analysis of coaxial line loss, power handling, voltage breakdown, etc. dated at least as far back as the 1920s, and there was a note about a specific 50 ohm coaxial cable product in a 1936 text.

I received many responses from readers, some of which confirmed portions of my own investigations, and some that offered more detail. Thank you to all who made a comment or offered a contribution to the discussion. A few are presented below (may be edited for length).

Gary Breed
Editorial Director

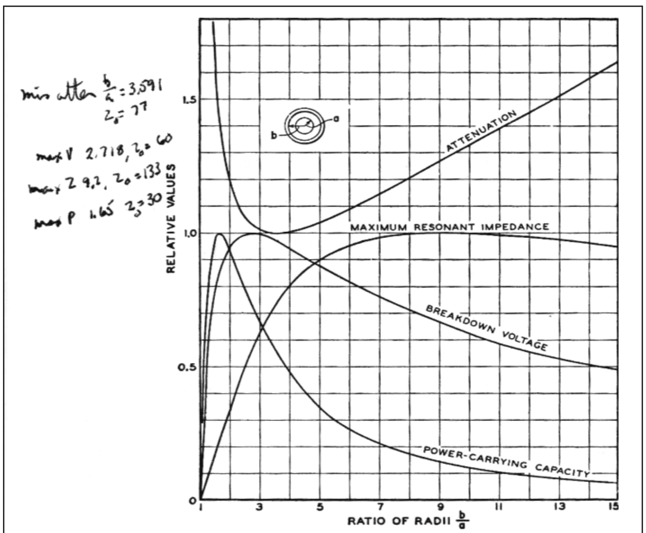

FIG. 4-3.—Various characteristics of a coaxial transmission line plotted as the ratio of radii of outer and inner conductors.

Dear Gary,

My 1958 Dover reprint of Theodore Moreno's 1948 book, *Microwave Transmission Design Data* presents in Fig. 4.3 [above] the relative values of attenuation, maximum resonant impedance, breakdown voltage, and power handling capacity as a function of outer to inner diameter ratio. You might not be able to read my notes next to the figure, but the maxima or minima are as follows:

Minimum attenuation:	b/a = 3.591	Z_0 = 77 ohms
Maximum voltage:	b/a = 2.718	Z_0 = 60 ohms
Maximum resonant Z:	b/a = 9.2	Z_0 = 133 ohms
Maximum power:	b/a = 1.65	Z_0 = 30 ohms

It appears that 50 ohms is a compromise between maximum voltage and maximum power. Long before cable TV, and until the advent of fiber optical cables, multi-tube buried 75-ohm coaxial cable provided a great deal of long-distance multichannel FDM and PCM interconnection, especially in Europe, the former Soviet Union, and Japan.

Ralph Gaze

Hello sir!

I read with great interest your Editorial in the June 2007 edition of *High Frequency Electronics*, which I just received yesterday. Working for Bird Electronic has its finer points, including the fact that 99.99% of our products are based on 50 ohms, and in finding and maintaining that impedance. Over the history of the company, many newsletters were produced and then went their way, including one entitled "Watts New From Bird." They were popular enough that in October of 1987, they were reprinted, one of which is attached, "Where Did 50 Ohms Come From?" I don't believe that it adds much to the historical context or the decision process that settled on 50 ohms, but does have a couple of tidbits for your database.

I cannot tell you how many magazines I receive each month, many of which end up in the "circular file" under my desk, but for the years I have been at Bird, I have all of the *High Frequency Electronics* that have ever arrived addressed to me. I use them in my training, in reference, and in my continued education. Thank you for your excellent publication.

Donald E. Huston
SOS Project Manager, GES Technical Trainer
Bird Technologies Group

Here is an excerpt from Bird's "Where Did 50 Ohms Come From?" explaining one aspect of 50 ohm cables, following a discussion of optimum impedances for loss, power handling and maximum voltage:

"We suspect that in the early days, when microwave power was hard to come by and lines, therefore, would not be taxed to capacity, low attenuation was the overriding factor which led to the selection of 77 (or 75) ohms as a standard for CW transmission. This, of course, resulted in hardware of certain fixed dimensions. Later on, when low loss dielectric materials were developed that made flexible microwave cables practical, the line dimensions remained unchanged to permit mating with existing equipment.

The dielectric constant of Polyethylene is 2.3. The impedance of a 77 ohm airline is reduced to 51 ohms when filled with Polyethylene."

Dear Mr. Breed,

Just read your editorial, "There's Nothing Magic About 50 Ohms." You have almost hit the nail on the head, but not quite. The origin of the 50 ohms actually comes from the geometric mean of these two quantities equal to 48.06 ohms, rounded to 50 ohms. Another important benefit: this value is close to the minimum voltage breakdown impedance value of 60 ohms.

This value was eventually accepted in an early standardization committee of the IRE, at that time. The concept proposal was being pushed at that time by the Bell Telephone Laboratories, primarily by Mr. Philip H. Smith, the inventor of the Smith chart, as the best compromise between the two values. Later, this proposal was also submitted to the ITU/CCIR, and was eventually accepted as a RF-standard value for the world-wide use. 75 ohms became the standard value for cable impedance when the work on video started to progress, because of its lowest loss/length property.

All this information I have extracted from my "ancient" notes, barely readable on a disintegrating page of paper, ready to be thrown out. Hopefully my brief comment clears up the issue.

Roman Z. Zaputowycz
Consultant, Satellite Systems

Editor,

Volume 9 MIT Radiation Laboratory Series, *Microwave Transmission Circuits*, edited by G. L. Ragan (1948) has a comprehensive discussion on the subject — (see pages 149-150, "The 50-Ohm Line as a Compromise Standard").

Dan Mawhinney
MMTC, Inc.

The section referenced above follows a discussion of coaxial line loss and power handling, as well as frequency-dependent effects. In it, Ragan says, "Depending on which of the five characteristics already mentioned is considered most important, this procedure would lead to the use of a number of different impedances over a threefold range, 30 to 93 ohms ... Obvious economy both in test equipment and in design work can be achieved if a single impedance can be chosen as a compromise standard. It has been found convenient to adopt 50 ohms as an impedance level offering a satisfactory compromise."

Gary,

I think you hit the nail on the head with the reference to textbook examples. If 52 ohms was a natural coaxial impedance with standard pipe and it is also a good compromise between 77 and 30 ohms, the easy explanation for 50 ohms and 75 ohms are ease of performing math without a calculator or CAD package.

Most of the old engineers I know wouldn't even break out a slide rule to divide or multiply by 50, making it a perfect characteristic impedance for a textbook example.

The next generation learned their RF from that textbook, not from the seat of their pants. I suspect that a many "magic numbers" in electrical engineering are simply the nearest mathematically convenient number from a textbook long forgotten.

Dr. Jeffrey C. Andle
Sr. Scientist—Sensor Element Technologies
Vectron International—Sensors and Advanced Packaging

Closing Comments

Some additional details noted by various readers include pros and cons of extending 50 ohms from cables onto printed circuit boards and other substrates, and whether it is an appropriate impedance for digital signals. There were also several notes on the effects of dielectric-loaded cables and how their optimum values differ from air dielectric lines.

Despite all the discussion and analysis, my personal view is that a 50 ohm standard "just happened." In other words, it evolved from many different inputs, analyses, practical considerations and other requirements addressed by individual engineers. I think this is what Ragan meant in his RadLab text when he used the unattributed phrasing "It has been found convenient to adopt 50 ohms..." because, even in 1948, there was no clearly traceable path to its origin.

This look backward has been thoroughly enjoyable, as evidenced by the reaction it generated. Once again, thanks for sharing your observations and insights on the subject. Let's hope that future generations of engineers also believe that engineering history is important!