WHERE DID 50 OHMS COME FROM?

The Bird signature describing the field we serve reads "Quality Instruments for RF Power Measurement." The standard coaxial line impedance for power transmission in the U.S. is almost exclusively 50 ohms. The question often arises why this value was chosen.

In concentric transmission lines, the electromagnetic wave is propagated through a dielectric medium bounded by two coaxial cylinders. Since current penetration at microwave frequencies is small (skin depth at 1 GHz in a silver conductor is approximately 0.00008 inches), the only important dimensions are the diameter (d) of the center and the bore (D) of the outer conductor.

For a coaxial line with small losses, such as used in the industry, the characteristic impedance is

$$Z_0 = \sqrt{\frac{L}{C}} = \frac{138.16}{\sqrt{\varepsilon}} \log_{10} \frac{D}{d}$$

where L and C are the inductance and capacitance per unit length and ε is the dielectric constant of the medium between the concentric cylinders (ε equals 1 for air).

Here are a few representative outer-conductor bore values for an airline with a one inch diameter center conductor:

30 ohms — 1.65"	100 ohms — 5.3"
50 ohms — 2.3"	150 ohms — 12.2"
75 ohms — 3.5"	

Different impedance values are optimum for different parameters. Maximum power carrying capacity, for instance, occurs at a diameter ratio of 1.65 which corresponds to 30 ohms. This is derived from V^2/Z_0 and from the maximum voltage V that can be sustained without breakdown. The optimum diameter ratio for voltage breakdown, however is 2.7, corresponding to an impedance of 60 ohms. This value has been used in some other countries of the world.

Power carrying capacity based on breakdown voltage ignores the current density, which is high at low impedances such as 30 ohms. Attenuation due to conductor losses alone is almost 50% higher at that impedance than at the minimum attentuation impedance of 77 ohms (Diameter ratio 3.6.) This ratio, however, is limited to only about one half the maximum power of the 30 ohm impedance line.

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:

$$Z_0 = \frac{77}{\sqrt{\varepsilon}} = \frac{77}{\sqrt{2.3}} = 51 \text{ ohms}$$

51 ohms is still in use today along with 51.5, 52, 53 ohms, even though the standard for precision work (and for most of our products) is now an even 50 ohms.

While minimum attenuation is desirable in signal transmission, equipment with a known amount of attentuation is a valuable tool in the laboratory.

Coaxial attenuators are used for a variety of applications such as isolation, comparison standards, power reduction at the source or at the receiving end, and for signal observance.

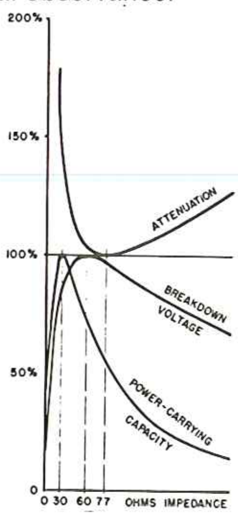

Fig. 1

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