Why 75 ohms?

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Even though the pace toward fiber optics in broadband communications, and in CATV especially, is speeding along at a breathtaking clip, coaxial cable will be with us for some time yet. Only the furthest extrapolations of proposed network architectures for the residential market (e.g., CATV) anticipate fiber all the way through the drop. Hence, this somewhat lighthearted treatment of a question fundamental to the use of coax ("Why 75 ohms?") is not out of order.

For use in video and broadband data transmission, two coaxial cable impedances are universally used—50 ohms and 75 ohms. While 75 ohms is the standard used in baseband video and CATV transmission, 50 ohms is widely used in various RF applications. How did these values come to be standards and why are they used in various areas?

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

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

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

The relation of the ratio of the diameters to the impedances of a few representative cables is shown in the accompanying table.

Different views

But back to the question of why 75 ohms. Unfortunately, there is not a unique and universally accepted answer to the question. I will present two schools of thought on the subject that although different have their advocates.

One view[1] forwards a proposal that follows a

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Impedances and diameter ratios

Cable impedance (ohms)	Diameter ratio outer conductor (D) / inner conductor (d) (inches)
30	1.65
50	2.30
75	3.50
100	5.30
150	12.20

Characteristic impedance of an air dielectric transmission line is directly proportional to the logarithm of the ratio of diameters.

logical analysis. 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. (See accompanying figure.) 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.

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 percent higher at that impedance than at the minimum attenuation 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.

It is likely 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 that led to the selection 77 (or 75) ohms as a standard for carrier wave (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.

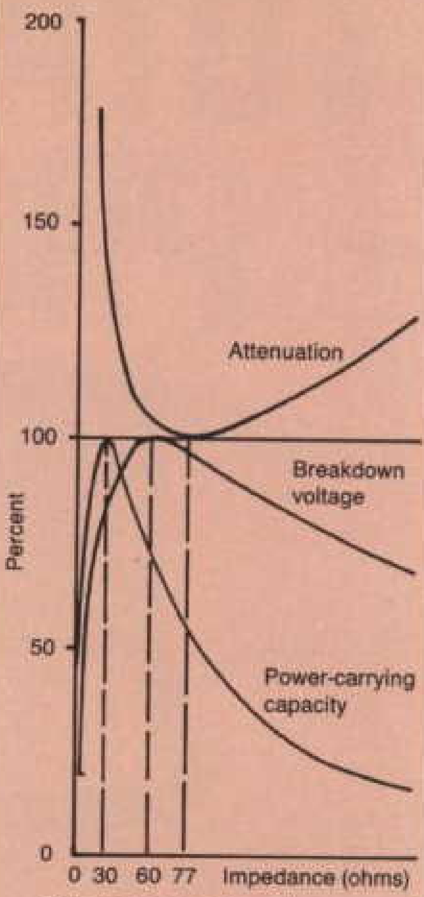
The dielectric constant of polyethylene is 2.3. The impedance of a 77 ohm air line is reduced to 51 ohms when filled with polyethylene.

$$Z_o = 77/\sqrt{\epsilon} = 77/\sqrt{2.3} = 51 \text{ ohms}$$

Even though 51 ohms is still in use today along with 51.3, 52 and 53 ohms, the standard for precision work is now an even 50 ohms.

Another view[2] on the origin of impedance values is a bit more anecdotal. It holds that since most efficient impedance to use when transmitting any signal—considering the voltages, currents and powers to be transmitted—is 75 ohms, this would be the only standard if these were the sole considerations. The telephone industry, followed by the TV industry, uses 75 ohms almost exclusively for the transmission of video baseband and IF frequencies. However, the military services during the period 1920 and 1940 were

Impedance and parameter values



Optimum parameter values occur at different impedance values.

faced with a differing need for low radiation angle omnidirectional antennas for broadcasting ship to ship, airport to tower to low flying aircraft and base station to ground troops. The only antenna that would give this performance was the vertical ground plane in its many forms, which turned out to be 50 ohms. The military standardized on 50 ohm impedance and spent vast sums of money developing cables and connectors for all its coax systems.

Well, as promised, there are two views on the origins of the two characteristic coaxial cable impedances widely used in broadband transmission. The first is a little more elegant—the type that often ends up in texts and leads students to believe that all the world evolved in a logical progression. The second reflects a view that treats life and advances a bit more pragmatically. You pays your money and you takes your choice.

References

[1] H. Heller, Bird Electronic Corp., *EDN*, Nov. 9, 1966.

[2] *Electronic Systems, Wiring and Cable*, Trompeter Electronics Inc.

Views expressed here are the author's and do not necessarily reflect those of Contel.