Dielectric absorption in capacitors causes "memory" or voltage recovery, it causes loss and thus increases D, the dissipation factor, and it causes a decrease in capacitance with frequency.

No capacitor is ideal except one using a vacuum, all others exhibit some loss in the dielectric used when an ac voltage in applied. At low frequencies, one can think of a dielectric material being a complex network of capacitances and resistances, the resistances being "leakage" resistances between the capacitances caused by the nature of the dielectric itself or by impurities in the material used. Any RC network, no matter how big, can be characterized by one of four "canonic" or generalized networks. One of these is an infinite number series resistances and capacitances all connected in parallel as in figure 1 (see reference 1). The separate resistor represents the actual leakage resistance. (The other canonic networks are a series connection of many parallel resistances and capacitances and two RC ladder networks, one with resistors in series and capacitors to a common point, the other with the resistance and capacitances interchanged.)

Let is consider the simplest case that exhibits all the effects of dielectric absorption, that of figure 2 where C_2 is much smaller than C_1. The effective capacitance of this network is $C_1 + C_2/[1 + (wRC_2)^2]$. One can easily see that the capacitance decreases with frequency, from $C_1 + C_2$ down to just C_1 at high frequency. More RC branches would add more terms like the second one, and enough such terms with different time constants could make the C vs frequency curve of most any shape as long as it decreases monotonically with frequency.

The D of this network can be written as $D = (C_2/C_1) wRC_2/[1 + C_2/C_1 + (wRC_2)^2]$. One can see that this is a humped-back curve of D vs frequency with a peak of about $(C_2/C_1)/2$ when $wRC_2 \approx 1$. Other added RC branches can produce a D vs frequency curve of any shape as long as D changes slowly. It can be shown that if D is constant, the change in capacitance with frequency is $(C_2 - C_1)/C = -D(2/\pi)\ln(f_2/f_1)$ where f_2 is the higher frequency and ln is the natural logarithm , see references 2 and 3.

Now imagine a voltage V applied to the circuit of figure 2 and applied long enough so that C_2 is fully charged. Then imagine the network short-circuited instantly discharging C_1 only. Now, if the voltage across the network is measured, it will slowly increase until the voltages across the two capacitors are equal and the voltage value will be $VC_2/(C_1 + C_2)$. This is the voltage "recovered", the voltage recovery is the percent of that recovered or $100\%C_2/(C_1 + C_2)$. This sometimes specified, but always after a specified time. The time constant in this case is $RC_1C_2/(C_1 + C_2)$. An actual capacitor, represented by many RC branches as in figure 1, would have some very long time constants, hours even days. This makes the measurement of the actual leakage resistance difficult.

An interesting experiment is to charge a previously discharged capacitor for a certain time, say an hour. Then short it quickly and then measure the current. The current will decrease slowly and after an hour will drop of quickly. The RC branches that got fully charged will get fully discharged, some that were only partially charged will be only partially discharged and will still be providing a very small current after an hour.

Capacitors made up of layers of two different dielectrics usually exhibit memory as would two capacitors with different dielectrics connected in series. Consider the circuit of figure 3 which is equivalent to that of figure 1 (but all the element values are different). This is the simplest example of the second canonic form mentioned above. Here C decreases from C_a at low frequency to $C_aC_b/(C_a + C_b)$ at high frequencies and $D = (C_a/C_b)wRC_b/[1 + wR^2C_b(C_a + C_b)$ which has a bump of about $(C_a/C_b)/2$ when $(wRC_b)^2$ is approximately equal to 1 ($C_b >> C_a$). The percent voltage recovery is $100\%C_a/(C_a + C_b)$. It's harder to see how the voltage recovery occurs in the circuit, but it does. This figure is a good representation of a mica capacitor which are layered and the mica layers can have different losses. The term "interfacial polarization" is sometimes used as the cause of memory, it would seem to apply to this circuit where charge can be trapped between layers.

Since dielectric absorption causes both D and memory, one is a good measure of the other. Air capacitors

capacitors have the lowest D and memory then, more-or-less in order, are those made of Teflon®, polystyrene, polypropylene, polycarbonate, mica, Mylar, paper and, the worst, electrolytic capacitors, tantalum and aluminum. Ceramic capacitors vary widely depending on their composition, some can be very good.

It doesn't take much imagination to see how a capacitor that exhibits memory would cause errors when used in a measurement circuit such a integrator. It would hold charges left over from previous measurements.

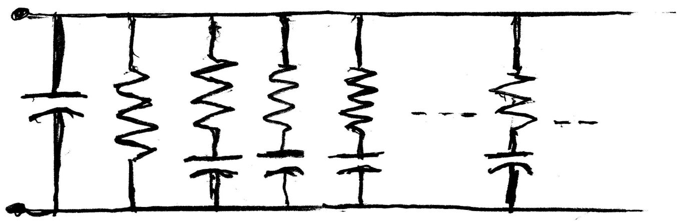

Figure 1

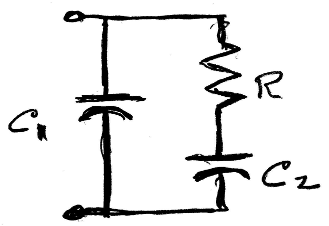

Figure 2

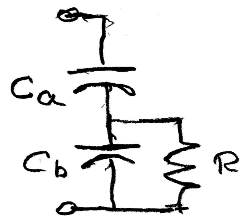

Figure 3

Relationships:

$C_a = C_1 + C_2$; $C_b = (C_1/C_2)(C_1+ C_2)$; $C_b/C_a = C_1/C_2$; Time Constant = $RC_1C_2/(C_1+C_2)$

$C_1 = C_aC_b\ (C_a + C_b)$; $C_2 = C_a^2/(C_a + C_b)$; Time Constant = RC_b

$R_1 = R_a(C_A + C_b)/C_a^2$; $R_a = R_1C_2^2/(C_1 + C_2)^2$; $R_1C_1C_2 = R_bC_aC_b$

($R_{1\ is}$ the resistance in figure 2, R_a that in figure 3. Note R_1 is somewhat greater than R_a.)

References:

1. Dow, P. C. Jr. "An Analysis of Certain Errors in Electronic Differential Analyzers II – Capacitive Dielectric Absorption", IRE Transactions on Electronic Computers Vol. EC7, pages 17-22, March 1958.
2. Garton, C. G., "The Characteristics and Errors of Capacitors Used for Measurement Purposes", Jour IEE 93, Pt II, 1946 pp 398-414.
3. Bray, P. R., "The Power Factor and Capacitance of Mica capacitors at Low Frequencies", Jour. Of Sci. Instruments, Vol. 10, February 1953. He gives a more general form: $dC/C = -(2/\pi)(\tan\delta)df/f$ which is valid if $\tan\delta$ is a known function of frequency ($D = \tan\delta$).