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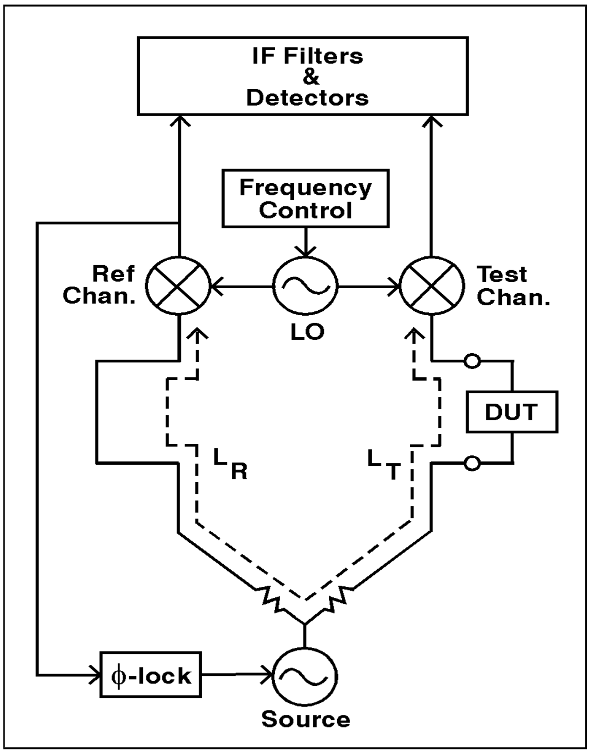
Measuring Electrically Long Devices with a Network Analyzer

A device with a long electrical delay, such as a long length of cable or a SAW filter, presents some unusual measurement problems to a network analyzer. Often the measured response is dependent on the analyzer's sweep time, and incorrect data may be obtained. At faster sweep rates the magnitude of the response seems to drop and looks distorted, while at slower sweeps it looks correct. This could indicate that a cable has more loss than it truly does, or that a filter has some unusual ripple in the passband which isn't really there. This article describes the cause of this behavior, and how to properly measure these electrically long devices. Two examples are presented to illustrate these effects.

Basic network analyzer operation.

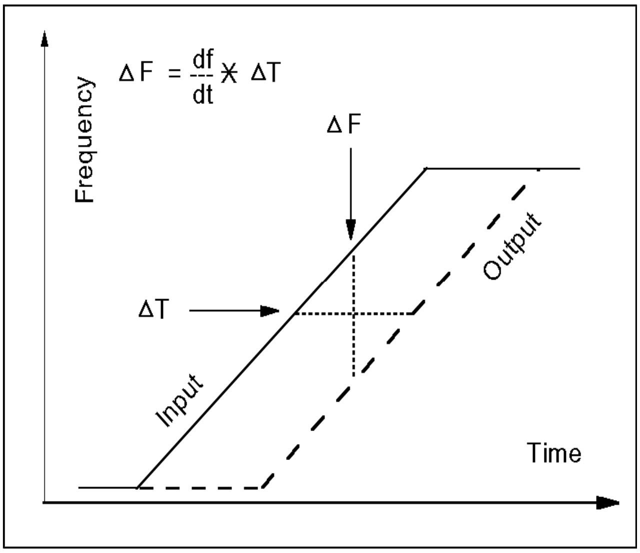
To understand this unusual behavior, it is first necessary to briefly consider how a vector network analyzer (VNA) works. Every network analyzer consists of two parts: a source and a receiver. In a VNA, the receiver is a tuned receiver; it uses mixers to downconvert the microwave signals to lower frequency IF signals, where the magnitude and phase information is measured .



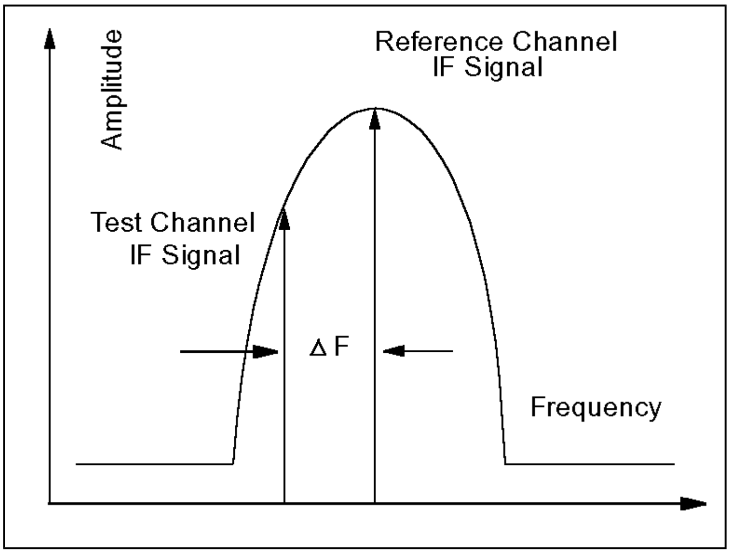
The Frequency Control tunes the receiver, and the Reference Channel's output is usedin aphase-lock loop to ensure that the source is locked to the receivers frequency. The IF filters set the measurement bandwidth of the receiver (typically between 100 and 3000 Hz), and the phase-lock loop ensures that the IF signal is centered in the IF bandwith. This is always true for the Reference Channel, no matter what the length of "Lr" (Figure 1); and is true for the Test Channel if L_R=L_T. Typically, VNA's are designed so that these two electrical lengths are equal when a test port connects the two ports.

The problem when measuring electrically long devices

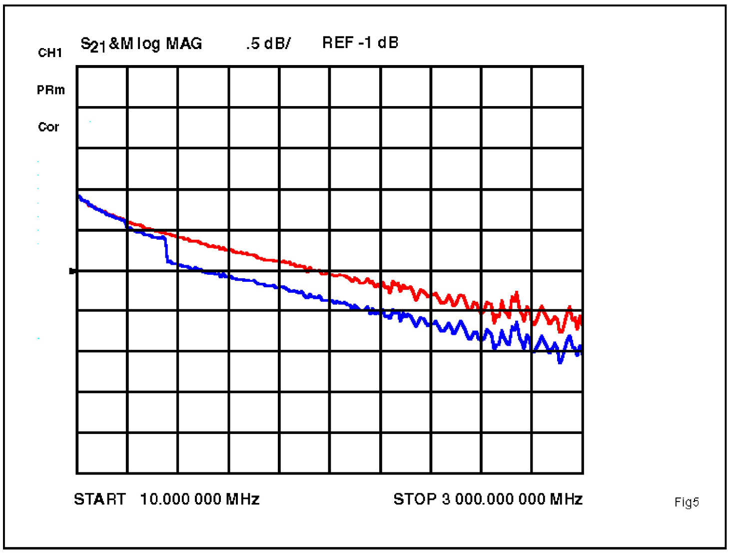
Now consider what happens when using a VNA to measure a device that has a long electrical delay, delta-T. Since the input signal to the device is sweeping frequency, the device's time delay causes a frequency shift between its input and output signals (figure 2). The frequency shift, delta-F, equals the product of the sweep rate and the time delay: delta-F = dF/dt * delta-T



In the VNA receiver, the test and reference input signals will differ in frequency by delta-F. The receiver is tuned to the reference signal frequency, because the frequency control loop locks on to the reference channel IF, so the test signal frequency is slightly different than the receiver frequency. This means that the test channel IF signal will not be centered in the IF filter, which causes the VNA to err in measuring its magnitude or phase (figure 3). The faster the analyzer's sweep rate, the larger delta-F becomes, and the larger the error in the test channel.



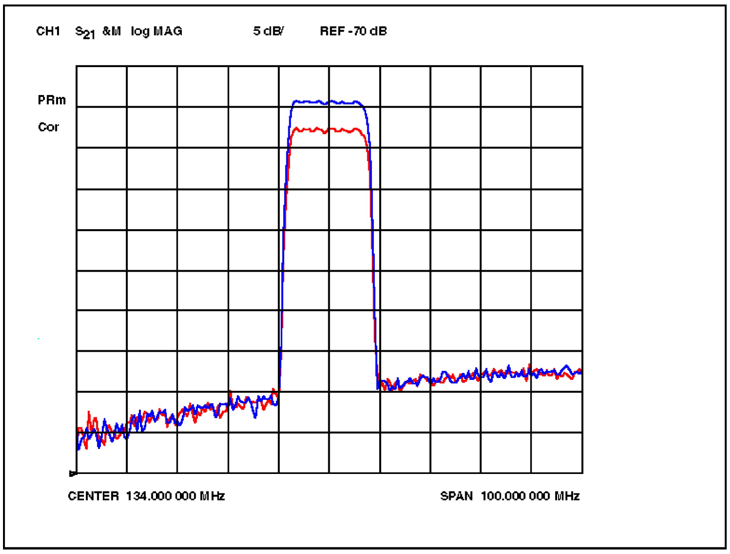
Some network analyzers do not sweep at a constant rate. The frequency range is covered in several bands, and the sweep rate may be different in each band. So if the operator sets up a broadband sweep with the minimum sweep time, the error in measuring a long device will be different in each band, and the data will be discontinuous at each band edge. This can produce some very confusing results, and it is difficult to determine the true response, as in figure 5.



This IF error can occur in other tuned receiver measurement systems, such as a spectrum analyzer and tracking generator combination. However, it does not occur in a scalar network analyzer, because the scalar analyzer uses broadband diode detectors instead of a tuned receiver.

Improving measurement results.

To reduce the error in these measurements, the frequency shift, delta-F, must be reduced. Delta-F can be reduced by decreasing the sweep rate, or by decreasing the time delay, delta-T. The sweep rate can be decreased, of course, by increasing the analyzer's sweep time. Figure 4 shows the data from two measurements of a SAW filter, which has a delay of 1.6 usec, on an Agilent 8510B/C Network Analyzer. In the first measurement, the analyzer's minimum sweep time (45 msec) was used, while in the second measurement the sweep time was increased to 400 msec. The error in the first measurement is entirely due to the frequency shift incurred when measuring this electrically long device at a fast sweep rate.



Selection of the appropriate sweep time depends on the device being measured; the longer the electrical delay of the device under test, the slower the sweep rate must be. A good way to tell when the sweep rate is slow enough is to put the VNA into a stepped frequency mode of sweeping, and compare the data. This may be called "List Frequency Sweep" or "Step Sweep" on the VNA's sweep menu. In this mode, the VNA does not sweep the frequency, but steps to each frequency point, stops, makes a measurement, then goes on to the next point. So the error does not occur in the stepped-frequency mode and it can be used to check the data; the disadvantage is that it is slower than sweeping. (Note that the Agilent 8753C/D and HP 8720B/C/D VNAs switch to stepped-frequency mode automatically if the sweep time is greater than 15 msec * number of points; e.g., 3.1 sec for 201 points.)

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