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Phase Stability Measurements versus Temperature for Several Coaxial Cable Types

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This document will present measured phase temperature stability performance of several types of coaxial cable. The cables were tested over the temperature range 10-40°C at 3 GHz using a HP8753A network analyzer. The insertion phase of the test cable with respect to the analyzer reference channel was measured as the test cable temperature was changed using a temperature chamber. Knowing the change in phase, it is then possible to calculate the phase/temperature coefficient, commonly given in ppm/°C.

The electrical length of a cable is given by:

$$L_e = \frac{L \cdot c}{v}$$

where L is the physical length, c is the speed of light in a vacuum, and v is the velocity of propagation within the cable. The quantity $(c/v)^2$ is the dielectric constant of the cable, and is always greater than unity, except for airlines. The network analyzer can be used to measure the electrical length, derived from the insertion phase measurement. Electrical length per electrical degree at a particular frequency is:

$$d = \frac{l_o}{360}$$

where l_o is the free-space wavelength. At 3GHz, the frequency used in these measurements, $d = 0.0278$ cm/°. By measuring the change in phase, $\Delta\Phi$, for a certain change in temperature, ΔT, the cables' coefficient for change in length per unit temperature can be determined:

$$r = \frac{\Delta\Phi \cdot d}{L_e \cdot \Delta T}$$

The quantity $\Delta\Phi \cdot d / L_e$ is the fractional change in cable length, and is often expressed in units of parts-per-million, ppm. It should be noted that r is generally a function of temperature, and for PTFE dielectrics varies quite strongly with temperature.

Seven cable types have been measured to date:

- FSJ1-50A: A semi-flexible ¼ inch coax with a corrugated copper shield, and polyethylene dielectric, manufactured by Andrews Corporation. The quoted phase stability specification is 10 ppm/°C.

- LMR240: A flexible coax with metal foil and braided wire shields, and polyethylene dielectric, manufactured by Times Microwave. The quoted phase stability specification is "<10 ppm/°C".

- Generic 141 Semi-rigid: Common semi-rigid coax with copper shield and PTFE dielectric. The phase stability specification is generally not quoted, but it is well known to be quite high near room temperature because the PTFE undergoes a rapid physical volumn change in that region.

- Belden 1673A: A conformable coax with metal foil and braided wire shield, and PTFE dielectric. The phase stability is not specified but is anticipated to be similar to 141 coax.

- LMR400: Similar to LMR240, but larger diameter.

- RG213: This is a double shielded version of RG9.

- FSJ057A-PSMSM: A semi-flexible coax assembly with corrugated copper shield, and polyethylene dielectric, manufactured by Andrews Corporation. The cable is similar to the Andrews FSJ1-50A, but with smaller diameter. Andrews does not quote phase stability for the FSJ057 cable.

The attached figure shows the measured stability coefficient for the tested cables. Phase was measured at four temperatures near 10, 20, 30, and 40C, and so the coefficients' variability with temperature are determined only to a 10 degree resolution in temperature. It can be seen from the figure that the FSJ1-50A cable performed as specified, that the LMR cables' coefficients were 2-3 times higher than specified, and that the 141 semi-rigid and the Belden 1673A coefficients are quite high in the 10-20C range.

The best phase stability performance found to date is that of the Andrews FSJ057 cable. Two 20-foot long assemblies were tested independently, and gave consistant results below ±5ppm/C. The FSJ057 cable assembly has soldered-on SMA connectors, which should offer better stability and robustness compared with the clamp-on connectors used with the FSJ1-50A. However, the connectors must be installed at the factory - Andrews will not sell cable and connectors separately. Figures 2 and 3 show network analyzer plots of the return and insertion losses for one of the 20-foot long cables. Performance seems to be acceptable to at least 20 GHz for many applications.

During the course of these tests, several of the test cable assemblies were temperature cycled between –17C and +40C. Measurements of the phase temperature coefficients before and after the temperature cycles showed no significant change in cable characteristics. Various manufacturer's literature indicate the importance of temperature cycling cables for phase stability, but our results did not find any such result. However, the cables we tested were in coils with gentle bends. The effects of temperature cycling might be quite different for cable assemblies with tight bends.

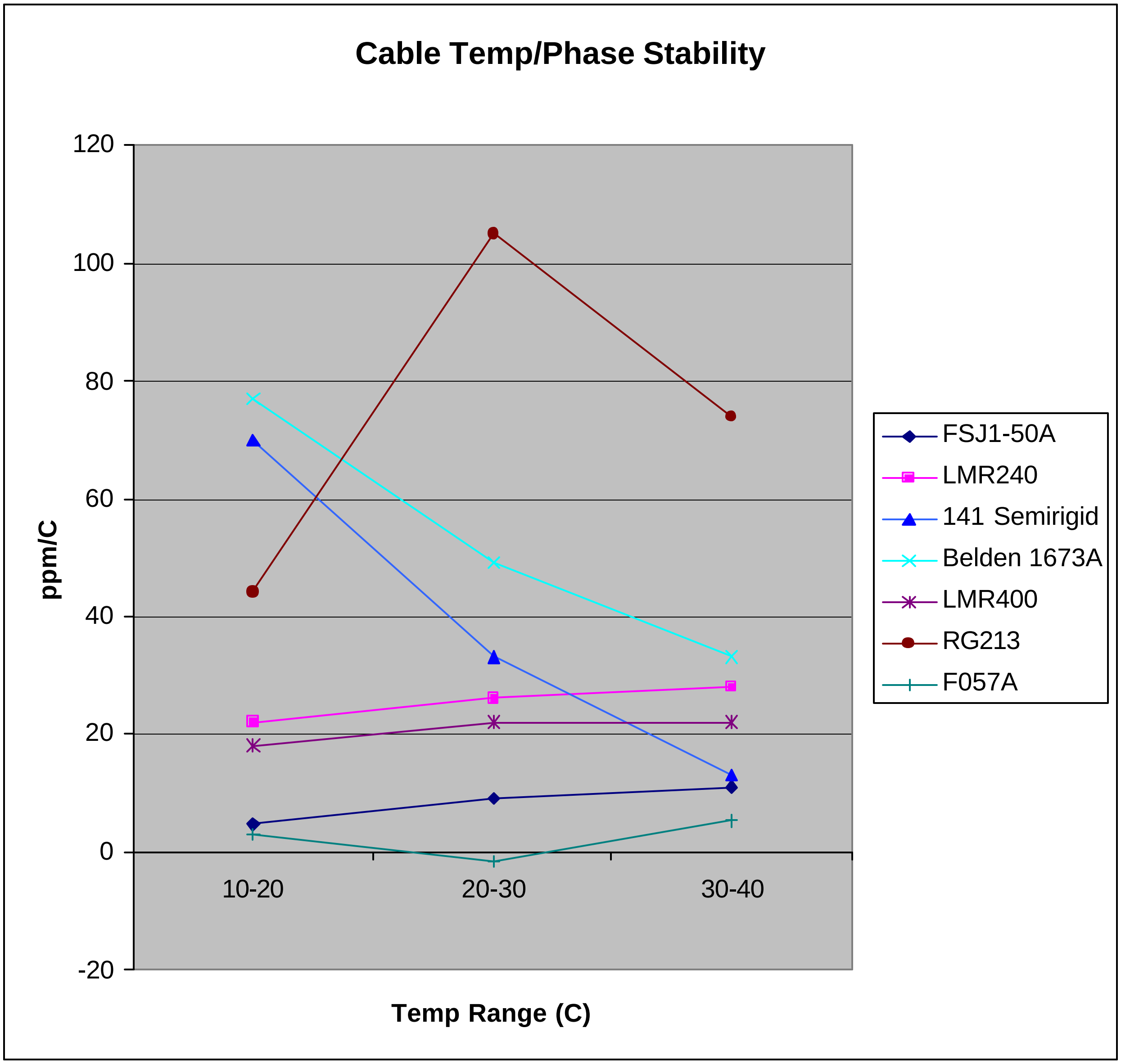

Figure 1: Plot of measured phase temperature coefficient for several cable types.

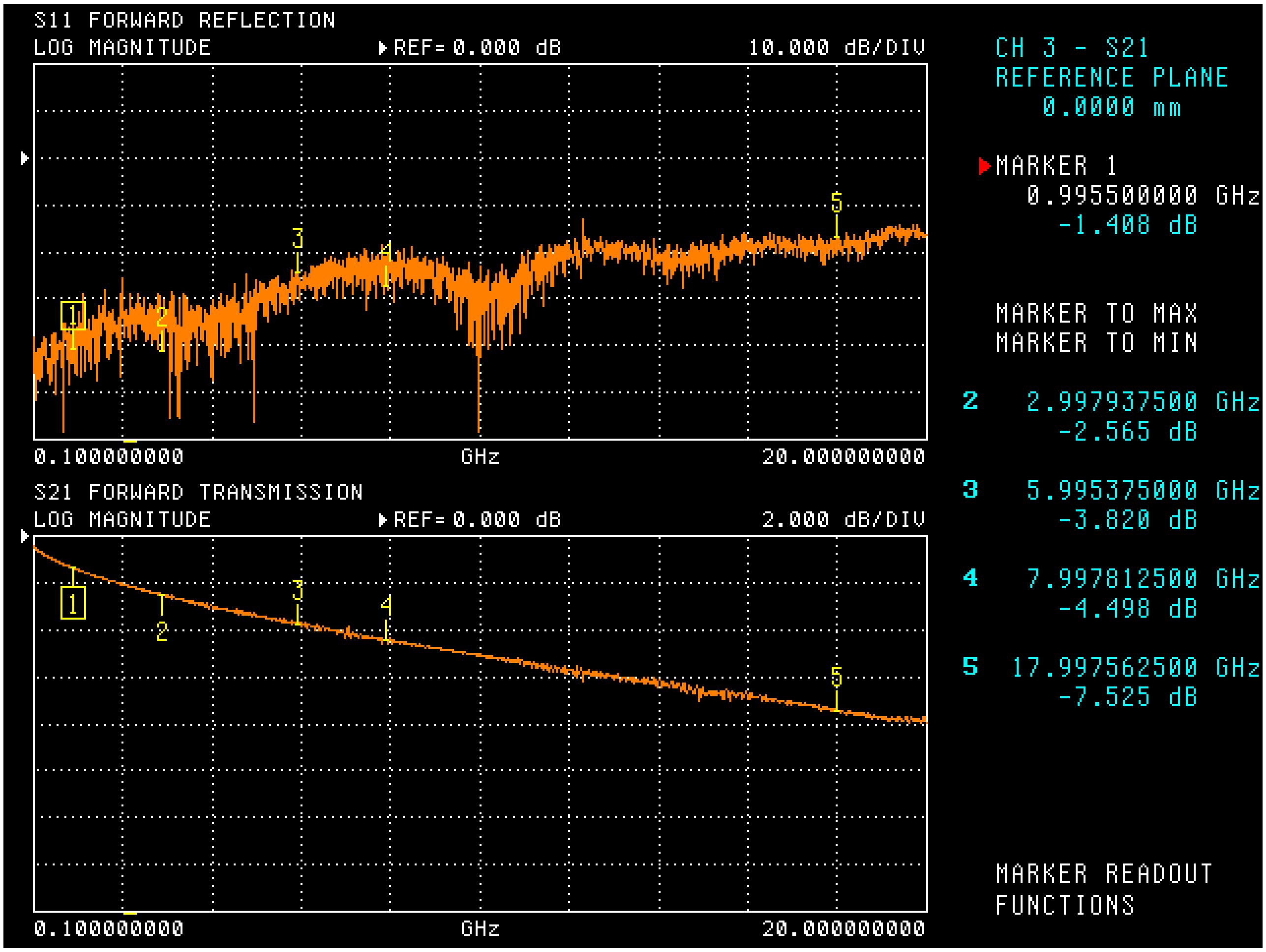

Figure 2: Network analyzer measurement of a FSJ057A cable assembly 19.6 feet in length. Frequency range is 0.1 to 20.0 GHz.

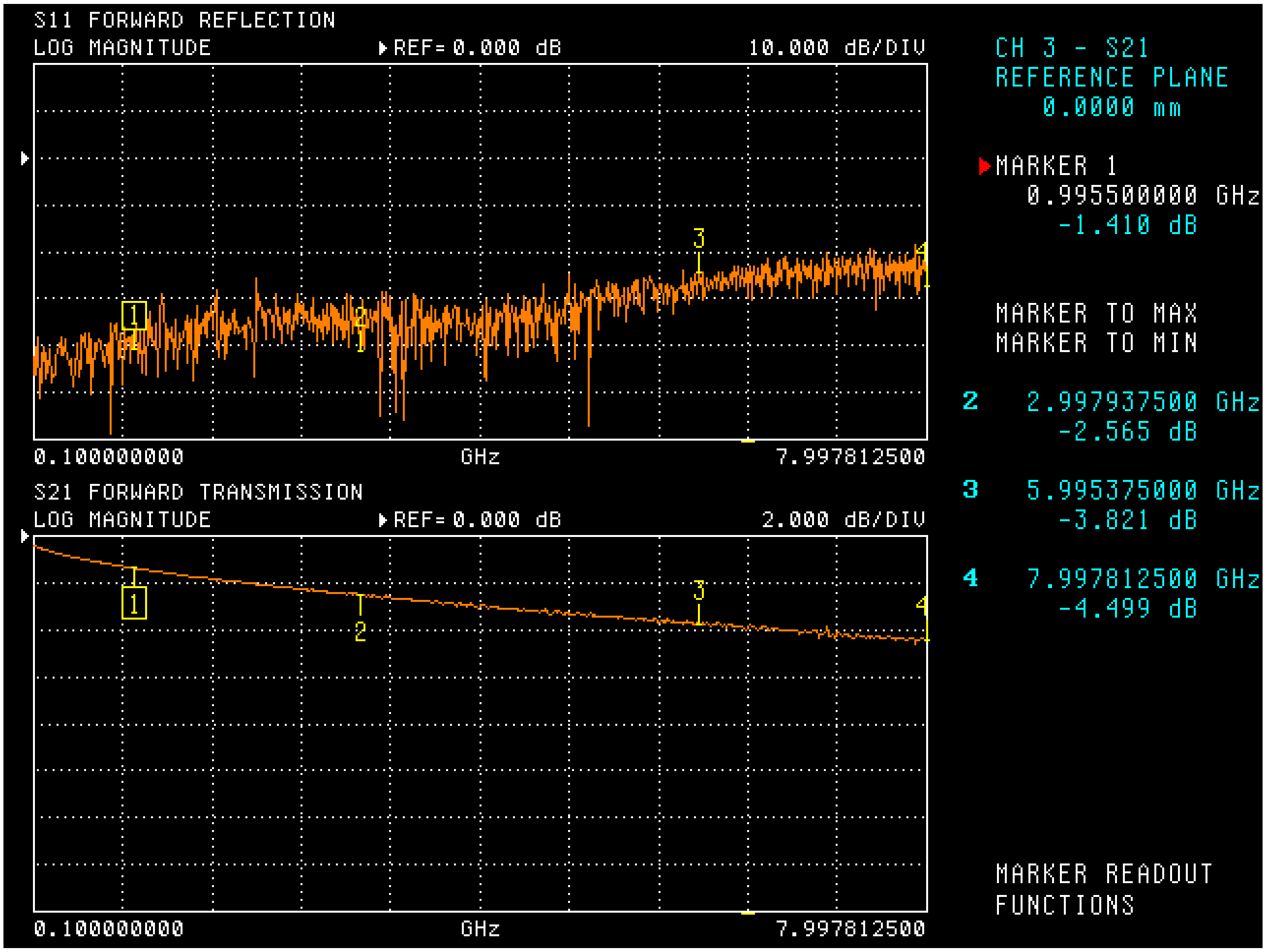

Figure 3: Same as Figure 2 except frequency range limited to 0.1 to 8.0 GHz.