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To: Mark 5 Development Group

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Subject: Measurements of cable delay with temperature and flexure

A simple accurate method for measuring cable phase delay change with temperature is to connect a signal generator to divide the power from a signal generator, feed the cable and then recombine the signal (through an attenuator) with the output of the cable. This combined output is then observed on a spectrum analyzer. As the frequency is changed the power goes through minima at

$$w\tau = \pi + 2\pi N$$

where $w$ = frequency in rad/sec

$\tau$ = cable phase delay at frequency $w$

$N$ = integer

If the separation $\Delta w$ between one minima and the next is measured we have

$$\tau = 2\pi / \Delta w$$

or $$\Delta\tau = -\Delta w \tau / w$$

where $\Delta\tau$ is the change in phase delay corresponding to a frequency change of $\Delta w$.

The method can be made extremely sensitive by adjusting the attenuator so that the power drops as far as possible at the null for which the direct signal and the cable delayed signals are 180˚ out of phase.

One advantage of this method is that the cable changes can be measured at any desired frequency although the precision improves as the frequency is increased.

The results for LMR-240 are as follows:

Length of cable 160’ (75 m)

Cable type LMR-240 UltraFlex

Temperature Change 74F (23 C) to 105 F (40 C)

| Frequency MHz | Delay change ps | ps/deg C | ps/deg C/m | ppm/deg C |
|---|---|---|---|---|
| 476 | -80±5 | -5.0±0.3 | -0.067±0.004 | -24±2 |
| 51 | -77±10 | -4.5±0.6 | | |
| 21 | -68±20 | -4±1 | | |
| 12 | -67±20 | -4±1 | | |

There might be slight reduction of the temperature coefficient with reduced frequency but given the errors I am not sure it is significant.

Change with 1 turn of 4” radius < 0.5 ps

**Comments**:

The LMR cable temperature sensitivity is higher than desired, however phase stable cable with an order of magnitude smaller coefficient is available at a cost of about $8/foot from Times Microwave or http://www.iw-microwave.com/.