INVENTION DISCLOSURE

1. **Invention Title.**

Method To Determine Complex Frequency Response of Downstream Cable Plant

2. **Invention Summary.**

Two signal generators are locked up to a precise time standard, one at a hub site and the other at a test site that might be a home or a tap location. The generator at the hub site is offset from the generator by a frequency, such as 30 MHz that can propagate upstream. With common command and control, both generators step their way through a frequency band that needs to be tested for complex frequency response. A mixer in the hub site mixes the received test signal with the local offset signal. This generates a signal (e.g. 30 MHz) that is sent back upstream where it is demodulated in the hub site for amplitude and differential phase response. A number of methods are disclosed to provide a frequency reference for the two generators. In an alternative embodiment the demodulation can take place in the field, which saves returning the signal over the upstream band. The field demodulation can be done by synchronous conversion down to baseband I and Q, or by conversion to an intermediate frequency (IF)

3. **Invention Description**.

   a. **Describe the invention in detail and/or attach a description, drawing(s) and/or diagram(s), if available.** See below.

   b. **Why was the invention developed? What problem(s) does the invention solve? How is it better?**
   Vendor engineers are now in the field trying to measure frequency response in the extended band. They have no cheap and easy way to get the job done.

   c. **Briefly outline the potential commercial value and customers of the invention.**
   There will be a big market for operators who want to know if their bandwidth above 550 MHz can be used for advanced services. Current Agilent test equipment to do the job is cost-prohibitive and not suited for field deployment.

4. **HOW is your invention different from existing products, processes, systems?**
In a general sense, this is a method to measure complex frequency response using a precise time reference signal on the transmit and receive side. This allows a measurement to be taken rather slowly, allowing averaging. Prior art ghost canceling reference signals have to be sent quickly to avoid phase drift between the sending and receiving time bases. Anritsu

and Agilent make equipment to make group delay and amplitude measurements, but they are based on sweeping a FM'ed signal across the band being tested.

Method To Determine Complex Frequency Response of Downstream Cable Plant

Background:
There is currently a need to determine if the upper bandwidth of cable plant is capable of supporting high-speed data services. Currently downstream services are 54 to 550-860MHz. It is believed that the taps and cable may be capable of service to 1.0 GHz, or possibly even 1.2 GHz. Currently, measuring the suitability of the bandwidth for high-speed data requires about $500,000USD in test equipment, primarily vector signal generators and vector signal analyzers. Thus there is a need to determine if many miles of cable plant is suitable for bandwidth expansion. The method described is much less expensive, can be made field-rugged, and thus may be placed into the hands of field technicians.
Proper characterization of the bandwidth for data signals requires both magnitude and phase response, as frequency response is complex.

See Fig. 1. At a headend, or hub site, a sine wave test signal 106 is generated that steps from the top of the occupied downstream band, say 550MHz, up to a higher frequency, say 1.7 GHz. A generator 102 is controlled by a computer (not shown) and steps in frequency over a frequency range. The generator 102 has low phase noise and very high frequency accuracy. This high frequency accuracy is due to a connection to <u>REF. A s</u>ignal source 108, which may be a standard 10 MHz lab reference source located in the hub site.

The downstream stepped sine-wave signal 106 is received in the field and mixed down to a frequency in the upstream band, 30 MHz for example. The field location may be a house or a tap. A field signal generator 104 that acts as a field local oscillator is stepped in frequency to exactly match the frequency steps of the generator 102 in the hub, but with a 30MHz offset. Steps may be 1 MHz as an example. A reference signal source, REF. B 110 with high stability controls the frequency and phase accuracy of the field sine wave local oscillator 104.

A mixer generates a 30 MHz test signal, which is filtered with a narrow bandpass filter, amplified and sent back upstream to the hub in an unoccupied band. At the hub, the 30 MHz signal is demodulated with a complex demodulator using a 30 MHz local oscillator with zero and 90 degree outputs. The 30 MHz signal is also locked to <u>REF. A 108.</u> The I and Q outputs are low pass filtered and recorded for each frequency.

Thus, as generator 102 steps in frequency, generator 104 matches its steps, with a 30 MHz offset. This produces a 30 MHz upstream signal which varies in magnitude and phase as the test signal is swept across the upstream frequency band. In the hub the 30MHz signal is demodulated with a complex demodulator and recorded. Because the upstream test signal is 30 MHz, IF and baseband filtering may be used on the complex demodulator to reduce the effects of Gaussian noise.
Synchronization of tuning may occur through a Cable modem (not shown) and PCs in the hub and field. Alternately, custom hardware and software can be used. Another method to control the headend signal generation and results viewing is thru a Web interface the technician uses in the field.
For this system to produce accurate results, it is required that signal generators 102 and 104 have low phase noise. REF. A 108 and REF. B 110 must also be very frequency-accurate, as the phase must not

drift for the duration of the sweep test, which can be several seconds. It is also necessary that generators 102 and 104 have similar or matching phase angles as they are shifted in frequency. They may optionally be calibrated together at the hub site prior to the start of the test.

The accuracy of REF. A and REF. B can be maintained in a number of ways. In a preferred embodiment, they can take their frequency reference from a Cesium-standard source. Another method is to use Global positioning system for high frequency accuracy. Another method is place a reference sine wave signal that is used by both REF. A and REF. B. on the downstream band at an unoccupied downstream frequency. This reference signal can be used to control a voltage-controlled oscillator (VCO) or a numerically controlled oscillator (NCO), a.k.a direct digital synthesis (DDS). Integrated circuits that can be considered for use are the Analog Devices AD9910 or the AD9956

It is expected that at some frequencies the downstream carrier may fall into a null, producing a 30 MHz carrier that also falls into a null. Thus, it is important to choose an upstream frequency band with low additive noise. Fortunately, averaging can be used as well as a narrow IF bandwidth to reduce the effect of noise.

Fig. 2 is another embodiment, but the complex demodulator is located in the field. This has an advantage of not requiring any upstream bandwidth for a return signal. After a test is finished the test results can be relayed back to the hub site via cable modem (or a carrier pigeon for that matter). Another advantage is that there is no additive noise from the return path link.

Fig. 3 is yet another embodiment with no return signal, using a complex generator that produces a 0 and 90 degree signals for a broadband complex demodulators. Note that maintaining good quadrature performance over a wide bandwidth is challenging, but a calibration routine with transmitter and receiver in the same location may decrease errors.

For the tuning synchronization you can take advantage of the GPS derived UTC absolute timing reference. You may decide, for example, that a tuning scan starts exactly at the beginning of every minute. If you coordinate parameters between HE and remote unit that indicate start frequency, number of carriers, scan interval per carrier and a slight modulation (to be used as a key) you can leverage that to match both tuning process. Alternately, the RF test signal can be turned off briefly before jumping to a next frequency to signal the receiver to also make a frequency jump. Tuning synchronization can also occur through a cable modem, but the latency will make a test take longer.

By:
Thomas H. Williams and L. Alberto Campos