Automated RF path characterization in mobile phone test systems

An automated application can make the process of RF path characterization easier and more accurate.

By Dennis Thiers

Today's mobile phone test systems make accurate RF level measurements. To ensure accuracy, offsets in RF levels caused by cabling, instrumentation or active components in the RF path must be considered. Methods used for characterizing and compensating for these offsets include the use of power meters and signal sources, as well as calibrated mobile radios. The problems in identifying RF paths in the system and associating path offsets by frequency with a given path are also part of the process that is used to correct measurements. Using a Visual Basic application, a test engineer can quickly define the RF paths in a test system, produce a table of offsets for each path and store these for use by the mobile phone test system.

RF paths

An RF path in a mobile phone test system is comprised of a series of components through which the radio signal is transmitted or received by the phone under test. The most obvious component is usually a coaxial cable and its connectors that lead from the phone, or a fixture carrying the phone, to RF instrumentation. Other common components of the path are RF relays, attenuators and amplifiers. A fixture is often used to contain the phone under test, and this fixture may have RF connectors and cabling that are also components of the path.

Experience has shown that this collection of components can be crucial to making accurate measurements of RF power levels transmitted and received by the phone. Variations in the RF power offsets caused by minor changes in the path can introduce significant error into these measurements. A method for capturing, storing and compensating for these offsets can improve the accuracy of power level measurements.

RF measurements

A straightforward method for measuring path offsets is to connect the path between an RF signal generator and an RF power meter. The signal generator is programmed to a known frequency and power level, without modulation. The RF power level at the signal generator output is then compared to the power measured at the power meter input. The difference is the RF offset for that particular frequency. Offsets are usually measured for the range of frequencies used in testing the phone. These frequencies correspond to the forward and reverse cellular or personal communications service (PCS) channel frequencies. However, disconnecting and reconnecting an RF path can influence the offset measurements by as much as 0.5 dB.

When an RF mobile station test set is connected to the path in normal testing use, it is possible to avoid disconnecting the RF path during path characterization. The RF mobile test station can act as a programmable source of RF power and can also make RF power level measurements at the appropriate channel frequencies. In this case, the phone end of the RF path is connected to a power meter. The test set is programmed to output a known frequency signal and power level, and the power meter reading is compared to the known level. The result is the RF offset including any inaccuracies in the RF test set. The RF path offset has thus been extended to include any offset introduced by the RF test set.

Another process for measuring RF offsets caused by RF path components in mobile phone test systems is the *Golden Phone* method. This idea is to use a calibrated phone and the RF test-set to source and measure all of the RF signals. In this way, it is possible to avoid disconnecting the RF path at either end. The calibrated phone is programmed to transmit at known levels on various channels, and those levels are then measured with the RF test set. The calculated offsets are stored and used exactly as those obtained by the other characterization methods. This method has the advantage of minimizing error caused by changing connections, but it has the limitations of accuracy and programmability imposed by the phone and the RF test set.

RF offsets

As an example, when characterizing an RF path that is part of a test system for advanced mobile phone ser-

AMPS Channel	Applied Frequency (Hz)	Measured RF Power (dBm)	Offset RF Power (dBm)	Value (dB)
1	869040000	0	–0.2	–0.2
71	871140000	0	–0.3	–0.3
141	873240000	0	–0.3	–0.3
211	875340000	0	–0.4	–0.4
281	877740000	0	–0.4	–0.4
351	879540000	0	–0.3	–0.3
421	881640000	0	–0.3	–0.3
491	883740000	0	–0.2	–0.2
561	885840000	0	–0.3	–0.3
631	887940000	0	–0.2	–0.2
701	890040000	0	–0.2	–0.2
771	892140000	0	–0.1	–0.1

Table 1. RF path offsets by AMPS channel.

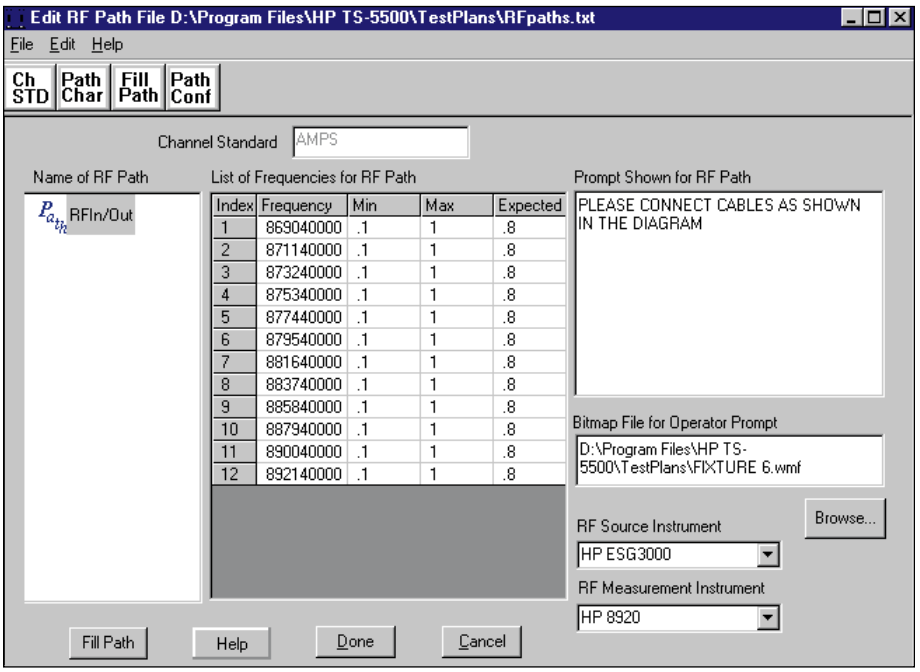

Figure 1. RF Path Characterization screen.

vice (AMPS) devices, several channels throughout the forward (base station transmitting) frequency range might be selected and 0 dBm signals applied to the RF path at those frequencies using an RF signal generator. Assume that the results, measured at the other end of the RF path using a power meter, are as listed in Table 1.

These offsets can now be stored and used to adjust the measured values or signal levels applied during the testing of phones connected to the above RF path. Assume that the required power level at the phone under test is –50 dBm and the channel used for the test is 211. The proper programmed setting of the RF test set is computed as

–50 dBm ⇒ Forward trasmit power level (at phone)

– – 0.4 dB ⇒ RF path offset

–49.6 dBm ⇒ Programmed power level (at RF test set)

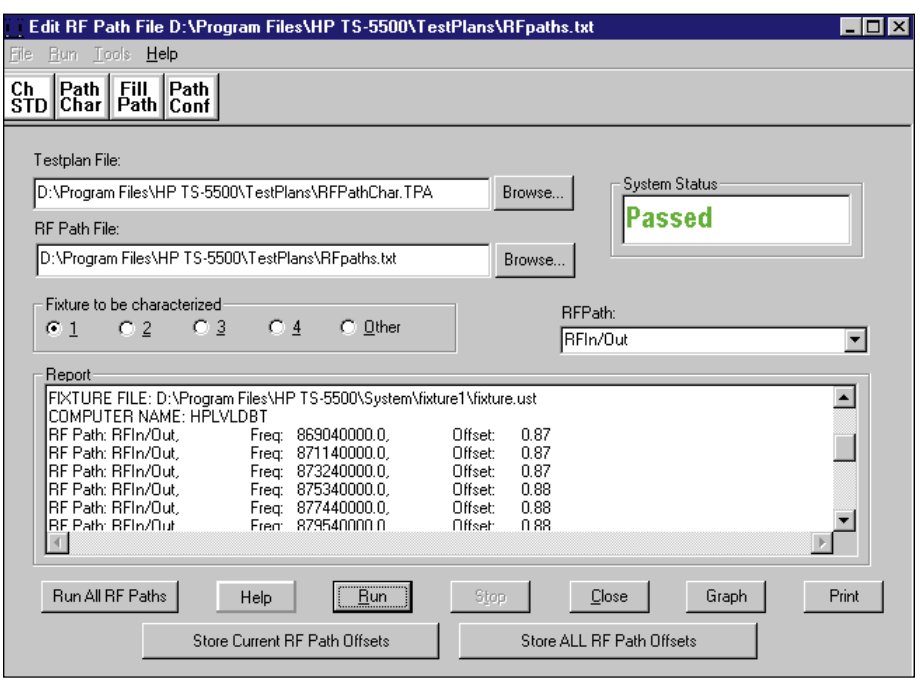

Figure 2. RF Path Characterization screen.

Tools for defining RF paths and characterization data

Test software provides for the use of tables of offsets for selected channel frequencies that are accessible for compensating all RF measurements and RF source settings. The RF offset tables are stored in a file that is loaded at runtime into the environment of the test executive program. The test executive makes the offsets available to tests and measurements contained in the phone test plan so that RF power levels can be adjusted as needed.

Because RF path offsets tend to vary with time, temperature and mechanical changes to the test system, it is necessary to periodically update the offset tables. A Visual Basic application has been developed that allows for automatic updates, once the RF channels and several other options have been selected. Some operator intervention is required to make any necessary connections to instruments.

The test engineer must decide what RF paths in the system are to be characterized. In most systems, only one RF path for each phone under test is needed. This RF path will connect the phone to the RF test set for both transmitting and receiving. In some cases, a separate path will carry the forward (base station transmitting) and reverse (mobile phone transmitting) signals. In more complex instances, paths to peripheral RF instrumentation will need to be characterized.

The test engineer must also choose which channels (frequencies) are to be measured, as well as operator or technician instructions to ensure that the proper connections have been made. Consider a simple case where there is one path. Figure 1 shows the *RF Path Configuration* screen of the path characterization program.

The test engineer first chooses a channel standard such as AMPS, PCS, global system for mobile communications (GSM) or digital communications system (DCS)-1800 that determines the forward and reverse channels and frequencies. The next step is to choose a set of channels from which the RF path offset measurements will be made. It is desirable to

have expected offset values, so that the measuring instruments can be set to the correct range, as well as maximum and minimum values, so the test operator can be informed if erroneous RF path offset values are measured.

Instructions to the test operator may also be entered in the appropriate field as text. There is a field that can be used to select a picture file of any standard format, such as .bmp, .wmf or .jpg. The picture file may contain a drawing or a photograph of the test system and any cable connections that may need to be made by the operator.

The program also associates a source instrument and a measurement instrument to be used in the measurement of all of the offsets for each RF path.

The previous data is entered for each RF path to be characterized. All of the path data is then stored into a file that is used when the RF path characterization test plan is run.

Measuring and storing offsets

Figure 2 shows the *RF Path Characterization* screen of the RF path characterization program. The test operator or technician runs the RF path characterization test plan generating tables of RF path offsets. As these offsets are computed, they are compared to the minimum and maximum values, and an error is raised if these limits are exceeded. The operator has the option of graphing the offsets vs. frequency along with the minimum, maximum and expected values.

If no errors exist, the operator or technician may store the offset values into configuration files that are used in the manufacturing test of mobile phones. Once these values are stored in the configuration files, they are automatically used in every measurement and source setting.

Conclusion

This system is flexible enough to allow for multiple RF paths, different channel standards, various types of source and measuring instruments, as well as RF paths that are a composite of different channel standards. At the same time, it is easy to use, and it allows for rapid configuration of RF path offset measurements and rapid updating and accessing of these important test system parameters. RF

About the author

Dennis B. Thiers received his B.S. in physics from the University of Illinois and his B.S. in computer science from Colorado State University. He has worked for Hewlett-Packard (HP) for 14 years, nine of those years as a software development engineer. He can be contacted at 970-679-2022 or by e-mail at *thiers@lvld.hp.com*. The RF path characterization program described in this article is the HP TS-5500 RF path characterization and measurement software program.