A New Antenna Monitoring System

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Monitoring the integrity of antenna systems is critical for efficient operation of a remote repeaters, paging or cellular/PCS base stations and is the subject of this article. A new technology approach to this challenge has been invented[1] which provides uninterrupted receive antenna monitoring for base stations.

Conventional Antenna Measurements

Terrestrial communication systems such as paging, two-way, land mobile and PCS/cellular concentrate transmission and reception within a 1 to 20 mile radius at base stations which include transmit and receive antennas. Because good antenna height is desirable for maximum radiation over terrain obstacles, base station antennas are often located in remote places, such as mountain tops or tall buildings where accessibility might be limited. The classic method used for monitoring the quality of an antenna has been to measure the amount of power injected into an antenna and compare the amount of signal that is reflected back. This calculation is known as the Standing Wave Ratio (SWR). Until now, antenna monitoring has been limited to transmit antennas, where the reflected signal is relatively high powered. The reflections are proportional to the quality of "impedance match" of the antenna, transmission line and source of RF power; a good indication of the system's efficiency or integrity. The greater the reflected energy, the greater the SWR mismatch or antenna damage[2]. Receive antennas require service disruption to inject a high-power stimulus signal to measure the magnitude of reflections.

Standing Wave Theory

The principal quantities to be measured on transmission lines or antennas are line current or voltage, and standing-wave ratio (SWR).

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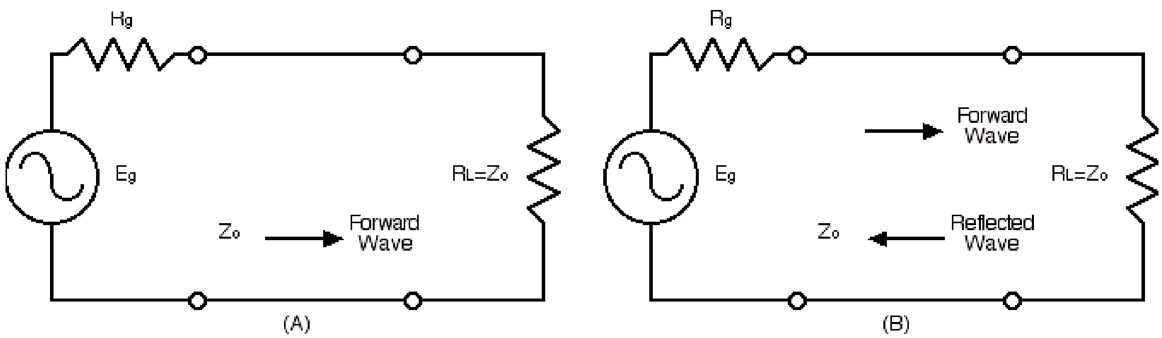
[1] US PATENT #6005891

[2] SWR is related to the magnitude of the complex reflection coefficient and expressed as: SWR= 1+ {p)/1-(p)

Measurements of current or voltage are made for the purpose of determining the power input to the line. In operation of base station transmitters, high energy radiated on a single channel is fed to a transmit antenna, and if significant energy returns, the SWR may be defined excessive. With the high power applied to a transmitter antenna, it is easy to detect (with a directive coupler and diode detector) mismatched loads. The rectified DC voltage will be proportional to the reflected signals. For base station receive antennas this is not so simple.



At A the coaxial transmission line is terminated with resistance equal to its Zo. All power is absorbed in the load. At B, coaxial line is shown terminated in an impedance consisting of a resistance and a capacitive reactance. this is a mismatched line, and a reflected wave will be returned back down the line toward the generator. The reflected wave reacts with the forward wave on the line. the amount of reflection depends on the difference between the load impedance and the characteristic impedence of the transmission line.

FIGURE 1

SWR Measurements

On parallel-conductor lines it is possible to measure the standing-wave ratio by moving a current (or voltage as in VSWR) indicator along the line, noting the maximum and minimum values of current (or voltage) and then computing the SWR from these measured values. This cannot be done with coaxial line such as found at base site transmitters and receivers since it is not practical to make measurements of this type of conductor inside the cable. The technique is, in fact, seldom used with open lines, because it is not only inconvenient but sometimes impossible to reach all parts of the line conductors. Also, the method is subject to considerable error from antenna currents flowing on the line.

Circuit description of the BAT™ receive antenna SWR monitor

The Base station Antenna Tester (**BAT™**)[3] automatically monitors ***receive antennas*** for proper operation. The system uses principles

[3] developed by Berkeley Varitronics Systems, Inc. of Metuchen N.J.

embodied in direct sequence W-CDMA, and integrates this signal over a long interval (called time spreading). The instrument uses a very low-power PN (pseudo-random) data signal transmitter (source), a PN data signal receiver (detector) and a pair of directional couplers connected in series with the transmission line to the receive antenna. Each directional coupler provides at least -30 dB directivity to prevent the PN energy transmitted from entering directly into the reverse coupler and masking reflected (desired) components of the PN signal.

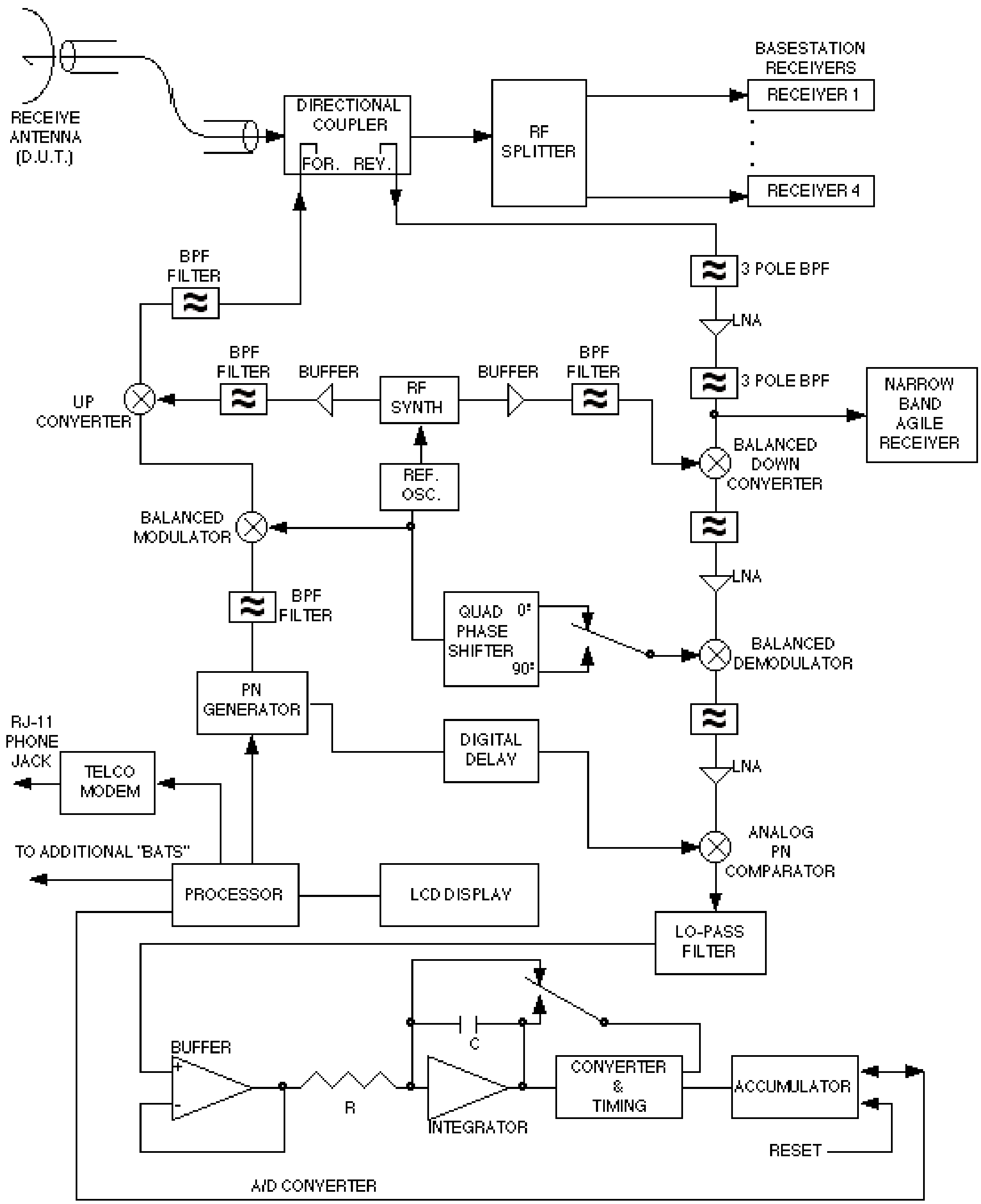


FIGURE 2
SIMPLIFIED DIAGRAM OF THE BAT™ AUTOMATIC ANTENNA MONITORING SYSTEM

On the transmit side of the system, the reference oscillator is modulated (encoded) with a high data rate, long Pseudo Random (PN) sequence (much like noise) which spreads out the signal's bandwidth to cover several megahertz. This wide-band modulated RF is then filtered and up-converted through the forward port of the directional coupler and applied to the base station antenna to be monitored. The energy presented to the receive antenna is at least -60 dB below the strongest expected receive signal, and hence poses no significant interference to these weak, mobile, narrow-band signals. In the simplest form, the modulation may be BPSK; simply a series of “ones” and “zeros”. The phase of the modulated waveform is shifted by 180° for a “1” or 0° for a “0”. The diagram shows QPSK modulation.

On the receive side of the system, reflected energy from the receive antenna under test (including noise and other RF signals) is received through the reverse port of the directional coupler, filtered, down-converted and fed to a 2-step (analog and digital) correlation system. First, the output of the down-converter feeds an analog PN comparator which attempts to match (bit by bit) the sense of the energy reflected with the original PN code transmitted. During this process, the correlator behaves like a matched filter, eliminating noise and unwanted signals; leaving only the reflected stimulus signal. It then measures the magnitude of integrated (PN) voltage to determine if it exceeds a predetermined threshold, hence a high VSWR. Most amazing, the PN receiver has a processing gain greater than +80 dB, allowing it to detect very weak signals in the presence of much stronger traffic and noise signals.

Referring again to Figure 2, compensation for the round-trip delay through the coaxial transmission line is provided to the receive correlator. The PN code is digitally delayed approximately 2 nanoseconds for each foot the antenna is located away from the antenna tester. The output of the analog

PN comparator produces a voltage which is fed to a low pass filter for integration. This voltage is buffered and then fed to an A/D converter which accurately translates the magnitude of the correlated waveform to a binary number for storing in the digital (memory) accumulator. This eliminates the nasty “droop problem” often incurred with integrate and dump circuits and allows relatively long integration periods, yielding high processing gains.

FIGURE 3
BVS BAT™ BASESTATION ANTENNA MONITOR

<u>Technical and Operational Advantages</u>

This low energy injection technique and high processing gain with analog and digital correlation of the reflected energy allows monitoring from antenna systems without shutting off receive signals. It operates in the presence of interference levels as high as -20 dB. This low power PN stimulus is only -80 dBm which permits the monitor to operate within recommended conducted spurious emissions for a base station. The system operates continuously, providing quick response in the event of antenna or feed line damage. In the event that the VSWR exceeds a prescribed threshold, the monitoring system dials-out via a data modem to immediately report this anomaly. Each **BAT**™ can monitor 3 antennas. Up to 16 **BATS**™ can be interconnected via telephone cable to its built-in network for measuring multi-sector antenna arrays while sharing a single telephone line for the modem.