A HIGH DYNAMIC RANGE MICROWAVE FIBEROPTIC LINK FOR TELEMETRY/TRACKING SYSTEMS

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KEY WORDS
Fiberoptics, remote antenna, dynamic range

ABSTRACT
This paper presents a simple, cost-effective solution that permits the antenna in a telemetry/tracking system to be placed at distances even greater than 20 km with virtually no signal degradation. By using a wideband, microwave fiberoptic link to pass the RF telemetry and tracking signals directly, the telemetry receivers can all be installed at the operator’s location. In essence, the only RF equipment that needs to be installed at the antenna site is the low maintenance fiberoptic transmitter which can be placed in a ruggedized housing at the pedestal. The actual system described herein uses a hybrid approach with some telemetry receivers at the antenna site and some remoted over the fiberoptic link. It is shown that the fiberoptic link used met and exceeded the system requirements. In addition, the design of the fiberoptic link is discussed and it is shown that the dynamic range achievable with this fiberoptic link is considerably higher than the system requirements in this case.

INTRODUCTION
Since 1987, analog fiberoptic links have been used for remoting microwave antennas. However, it is only within the last two to three years these links have been available with dynamic range sufficient for telemetry/tracking systems. Many systems have antennas placed in somewhat inaccessible places far from the operator. Also, because security is necessary, government contracts for these systems are requiring fiberoptics for signals to and from the antenna. So far, all of the fiber links that have been used are low frequency (< 500 MHZ) or low speed digital. These approaches end up requiring many lines (10 -
and they also require that the receivers and other equipment the user would like to have access to, must be placed remotely at the antenna site. Since these units must be under operator control they are remotely controlled via a GPIB bus which, in turn, must receive control data through an interface with the communications link. Finally, all of this equipment must be placed in an environmentally controlled structure.

With a high dynamic range Ortel fiberoptic link the RF signals can be transmitted directly over fiber so that the receivers can be moved to the operator’s location and the number of fibers needed is cut to a minimum. This approach was adopted by Datron for one of their systems which was recently installed and is described here. The design and performance capability of the fiberoptic link is also given.

WIDEBAND TELEMETRY/TRACKING ANTENNA SYSTEM

Datron Systems is a manufacturer of telemetry and satellite tracking antenna systems. During 1991, Datron developed two similar telemetry/tracking antenna systems for the U.S. Government. These antennas were eight foot, high dynamics trackers capable of operating at any frequency between 1400 and 2400 MHz. Equipment provided included the antenna, dual polarized SCM feeds and LNAs, servo controller, two Antenna Control Units, and a microwave fiberoptic link.

Total distance from the antenna to the remote control facility was up to eleven miles. The fiberoptic link had to traverse this distance while operating anywhere in the 1400 to 2400 MHz range over a 60 dB dynamic range. This dictated that a high performance microwave fiberoptic link be used.

Figure 1 shows the overall block diagram of the Telemetry/Tracking Antenna System. The final design concept includes an Ortel DFB laser transmitter and companion photodiode receiver. This combination gives excellent performance over the 11 mile path, but with a slightly lower dynamic range than required. A secondary concern was to prevent overdrive of the laser diode should a target stray too close to the telemetry antenna. The addition of a wideband AGC amplifier in front of the laser transmitter increased the dynamic range to over 60 dB while unconditionally protecting the laser transmitter.

Figure 2 shows the block diagram of the signal chain that was used to analyze the performance of the system. The AGC amplifier was designed to provide a constant 40 dB gain for input signals up to -35 dBm. For signals above -35 dBm, the gain is reduced so that the output is maintained constant at +5 dBm. For weak signals, the AGC amplifier acts as a simple gain element. The time constant of the AGC was chosen at a moderately slow 100 msec, which is the longest expected time constant necessary. The AGC time constant of the telemetry receiver downstream can then be set to a shorter time constant if desired.
Even higher dynamic range is possible with selection of higher performance RF components and further fine tuning of the gain distribution. The final design used for this system is an optimum selection which meets the design criteria while using readily available commercial components.

Figure 3 shows the noise temperature analysis of the link. The analysis shows that the 11 mile fiberoptic link adds only 0.55 dB degradation to the basic antenna and LNA noise temperature. Actual measured data on the final system showed that this performance was exceeded. In fact, degradation in noise floor due to the fiber link was practically unmeasurable. Two tone intermodulation products were measured at better than -30 dBc over the entire dynamic range of the system. Interestingly, with the particular choice of RF components, the LNA was the first component to saturate. The result was that the combination of a high performance fiberoptic transmitter/receiver pair and a wideband AGC amplifier give excellent bandwidth, high dynamic range and all design criteria were met at a moderate material cost.
Figure 3. TELEMETRY RECEIVER NOISE TEMPERATURE ANALYSIS - 11 MILE LINK

NOISE:

ANTENNA NOISE TEMP: 213.6 K
LNA NOISE TEMP: 120 K
AGC AMP: 5 dB = 630 K
FO SYSTEM: 55 dB = 91,700,000 K
POST POST AMP: 4 dB = 440 K
RECEIVERS: 12 dB = 4,400 K

TOTAL RECEIVER SYSTEM GAINS:

AT LNA OUTPUT: 40 dB = 10,000
AT AGC AMP INPUT: 27 dB = 500
AT FO TX INPUT: 67 dB = 5,000,000
AT POST POST AMP INPUT: 13 dB = 20
AT RECEIVER INPUT: 31 dB = 1200

NOISE CONTRIBUTION OF EACH RECEIVER SYSTEM ELEMENT:

ANTENNA: 213.6 K
LNA: 120 K
AGC AMP: 630K/500 = 1.3 K
FO SYSTEM: 91,700,000K/5,000,000 = 18.3 K
POST POST AMP: 440K/20 = 22 K
RECEIVERS: 4,400/1200 = 3.7 K

TOTAL: 378.9 K = 25.78 dBK

TOTAL NOISE OF ANTENNA PLUS LNA: 213.6+120 = 333.6 K = 25.23 dBK

TOTAL DEGRADATION OF ALL ELEMENTS PAST LNA: 0.55 dB
FIBER LINK DESIGN AND PERFORMANCE

DESIGN

The telemetry/tracking fiberoptic link is depicted in Figures 4 and 5. The transmitter (Figure 4) has two RF paths, one for RHCP and one for LHCP. The first block consists of a fixed or tunable bandpass filter. This is necessary to keep out-of-band signals from mixing with the signal of interest causing in-band distortion products since the fiberoptic link itself covers the entire 100 MHZ to 5 GHz range. Field tests have confirmed the benefits of this approach in a busy airspace to prevent degradation of received telemetry.

Figure 4. Fiberoptic transmitter block diagram.

The next block is an automatic gain control unit (AGC). The amplifier is chosen so that the link meets the sensitivity requirement for the longest link. The AGC may be designed to respond to the RF power at the laser input or to the telemetry receiver output. The latter would require a return path from the telemetry receiver to the fiberoptic transmitter at the antenna pedestal. The locally controlled AGC is simpler and has been found to be more than adequate. In this case, the AGC reduces its gain when the input RF power to the laser exceeds some maximum level (+5 to +15 dBm depending on linearity requirements).
Figure 5. Standard 19" rack mounted microwave fiberoptic receiver.

The entire unit could be mounted in an outdoor enclosure approximately 30"x 24" x 8" and will run on AC power available at the antenna. This enclosure would then be mounted inside the antenna pedestal. The fiberoptic receiver would be a standard 19 inch rack mounted unit and would mount in the rack with the telemetry receivers. This is shown in Figure 5.

Figure 4 indicates low reflection, FC/APC optical connectors but, if the fiberoptic cable connection is to be exposed to the weather, the connector used must be a ruggedized, MIL-spec connector such as the duplex TFOCA (tactical fiberoptic cable assembly) developed by AT&T. The connector is for a duplex (2 fiber) cable and is based on the biconic or the ST connector. The optical return loss must be > 35 dB.

PERFORMANCE

The worst case dynamic range for the fiberoptic link is shown in Figure 7. The dynamic range shown is from the noise floor to a given maximum RF input signal level. For the Datron system this signal level was +5 dBm. The high performance laser transmitters available today have input 1 dB compression points that exceed +15 dBm and input IP3 greater than +30 dBm. The laser should be protected against RF overdrive as in the Datron system. The figure shows the worst case performance of the fiberoptic link by itself.
and with the AGC and postamplifier included. In both cases, it was assumed that the maximum input to the laser is +5 dBm. Also shown are some measured values for the fiberoptic link itself.

![Graph](image)

**Figure 6.** Fiberoptic link dynamic range from noise floor to +5 dBm RF input.

The dynamic range will be improved by increasing the input RF signal to the laser. Care must be taken in choosing the AGC so that the output stage of the amplifier does not introduce any unwanted nonlinearity. For very long links (> 30 km), it is possible to maintain good dynamic range by the use of a fiberoptic repeater in the form of two cascaded fiberoptic links.

**CONCLUSIONS**

Using a high performance microwave fiberoptic link to remote the antenna can greatly increase the simplicity and lower the maintenance of a telemetry/tracking system. Readily available fiberoptic links add considerably to system design flexibility with virtually no signal degradation.